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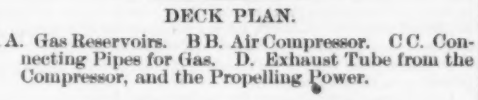
ENGLISH AND FRENCH ARMOR-CLAD SHIPS.

THE new French, twin-screw, armor-clad vessel Caïman was recently launched from Mourillon Dockyard. In using the expression new, the term must be understood to apply in the sense that the vessel has never been in the water, for as she has been on the stocks for the last seven years, and as two or three more years will be required to complete her, it is questionable whether she will not have grown old before she is finished; and it would seem that they do not always manage these things so much better in France. The Caïman is a turret ship, and has been built to the designs of M. Sabatier, the well known Director of Naval Construction. The *Times* gives the following details: She is 285 ft. 6 in. long, including the bow, which projects 16 ft. The maximum width is 59 ft. 1 in., and the depth 23 ft. The top of the turret is nearly 20 ft. above the water line. The armor consists of Creusot steel plates with a maximum thickness of just under 20 in. (50 centimeters), and this thins out at the bow and stern. The vital parts are protected by a steel deck with plates 2·8 in. (7 centimeters) thick, supported by a wood backing 6 in. thick. The main engines are each to be 750 horse power, and are supplied with steam by twelve boilers in four groups, each separated by water-tight compartments. The speed expected is 14½ knots. The weight of machinery and equipment will be over 2,000 tons, toward which the machinery contributes 1,200 tons and the armament 50 tons. The arrangements for pumping out the vessel in case of leakage are very complete in the matter of directing all the pumping power to any required spot. There are two centrifugal pumps, two large pulsometers, besides the regular bilge pumping arrangements. There are two movable keels, in case the vessel takes the ground.

Another new vessel is shortly to be laid down on the Tyne for our own government; Messrs. Armstrong, Mitchell & Co. having been intrusted with the building of the Renown, which will be the largest ship commenced for the British Navy since the Inflexible was begun twelve years ago. She will be a single turret armor-clad vessel with twin screws. Her dimensions are to be as follows: Length, 340 ft.; breadth, 70 ft.; and displacement, 10,500 tons. Her chief armament will consist of two 110 ton breech loading guns similar to those that are to be placed in the Benbow, recently launched at Millwall. The turret will be protected by 18 in. steel faced armor, and there will be a partial water-line of the same thickness. There is also an armored deck 3 in. thick. In the forepart will be carried twelve 6 in. guns, and aft an 18 ton stern chaser, while on the broadside will be a large number of machine guns. There will also be a powerful armament of Whitehead torpedoes. The ram bow is to be, according to the *Newcastle Chronicle*, from which we gather these details, of a strength never yet reached in any previous vessel.

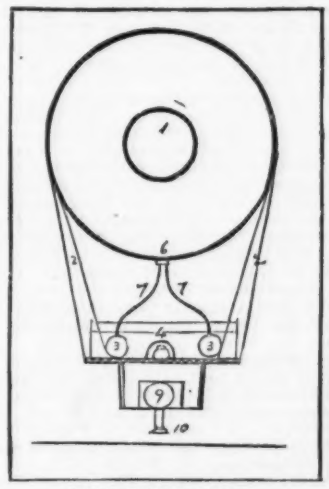
A PROPOSED WAR BALLOON.

THIS new war balloon, of which a sketch has been sent to us by Mr. Carlton S. Moore, of Philadelphia, is the invention of General Russell Thayer, of Philadelphia, who, the *American Register* tells us, "has received



DECK PLAN.

A A. Gas Reservoirs. B B. Air Compressor. C C. Connecting Pipes for Gas. D. Exhaust Tube from the Compressor, and the Propelling Power.



END ELEVATION.

1. End of Balloon. 2 2. Suspenders. 3 3. Hydrogen Reservoirs. 4 Exhaust Tube from Compressor. 6. Supply Valve for Hydrogen. 7 7. Connecting Pipes for Gas from Reservoirs. 9. Container of Engine. 10. Exhaust.

instructions from the Ordnance Board of the United States Army to begin work at once upon a monster air-ship, which is likely to be one of the most destructive implements of battle known to modern science. It will have an ascending force of seven tons, will cost nearly $10,000, and will have a length of 66 feet and a diameter of 60 feet. It is known as the 'Dirigible War Balloon,' is cigar-shaped, and pointed at both ends, and, independent of wind, it has a speed of thirty miles an hour, the motive power being compressed air, which is accumulated by machinery and discharged at the rear end. The air-ship can be steered in any direction, and tons of dynamite can be dropped as it sails over a fortification or a fleet of ships."

Mr. Moore writes that Earl Granville has cabled to the inventor for plans and full information respecting the new aerial machine.—*London Graphic.*

ENGINEERING PROGRESS IN 1884.

THE Thirteenth Annual Convention of the American Society of Civil Engineers was held at Deer Park, Maryland, on the 24th June. Among the interesting places visited by the members were the Baltimore water works. They were conveyed by train to the impounding reservoir at Loch Raven on the Gunpowder River, the new source of water-supply. Here the party examined with a great deal of interest the masonry dam and gate-house.

The dam is 300 feet long, and has an overfall the entire length, the overfall being in the form of a reverse curve; its total height from foundation to crest being 29 feet, the foundation being 13 feet below the original surface.

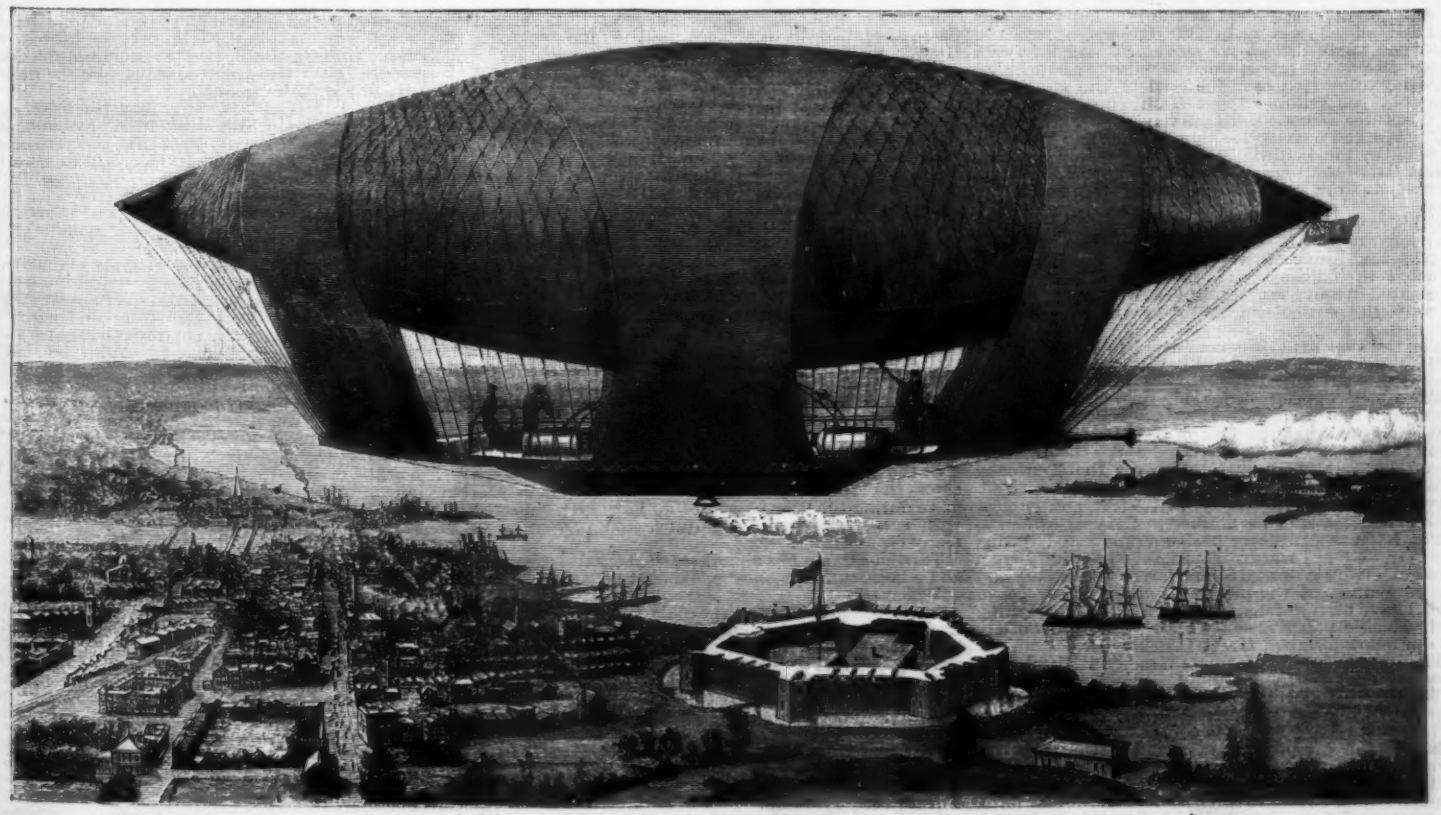
The dam, with its wing, walls, and gate-house, cost about $265,000. The reservoir formed by this dam is about five miles in length by 100 to 800 feet in width, covers 116 acres, and contains 510,000,000 gallons.

At the gate-house the water enters a circular brick conduit, 12 feet in diameter, built mostly in rock tunnel. This tunnel is nearly seven miles in length, has a gradient of one foot per mile, a daily capacity of discharging 170,000,000 gallons, and was completed at a cost of $1,780,000.

Lake Montebello was next visited. This is a settling reservoir at the termination of the conduit from Loch Raven; is built in a natural ravine, and as the original water-course in this ravine was unfit for use, it was diverted from its course, and now flows around the reservoir in a brick conduit, nine feet in diameter, this conduit being also utilized for overflow or waste discharge from the reservoir.

Lake Montebello is irregular in shape, has a maximum depth of 30 feet, a water surface of 59 acres, and a capacity of 496,378,000 gallons. The gate-house is so situated and arranged that it serves for both influent and effluent circulation, being maintained by an effluent conduit carried to the further extremity of the lake.

From Lake Montebello, which is a settling and storage basin, the water is conveyed to Lake Clifton, which is now in progress of construction, the substructure of the gate-house only being completed. Here the engineers saw the operation of making a pud



A NEW NAVIGABLE WAR-BALLOON.

die embankment (some of the younger members for the first time). The embankment of Lake Clifton is to be 40 feet high, has an exterior slope of 4 to 1 and an interior slope of 3 to 1. The material for the embankment is taken from the bottom and one side of the reservoir, and is an excellent material for the purpose, being a stiff clay, of a tenacity requiring a team of 12 mules to break it with the plow. The embankment is formed by making two parallel walls with a space between. The walls are built up in 3-inch layers of clay, thoroughly rolled with heavy grooved rollers. When the two walls have reached a sufficient height, water is turned into the space or ditch included between, and then puddling material, after being broken finely, is shoveled into the water by laborers and allowed to settle and compact itself. The completed lake will form a perfect ellipse, and contain about 265,000,000 gallons.

ENGINEERING PROGRESS IN 1884.

In the evening President Graff delivered his annual address, which was a *resume* of engineering progress during the year.

The President's address is as follows:

It is somewhat difficult to realize that a full year has passed over our heads since many of us met in the city of Buffalo.

A few years since it would have been hard to have recorded much advance in so short a time. Now, the strides made in inventions and discoveries are so rapid, and the noble works undertaken by our profession are so numerous, as to preclude at this time more than brief mention of but a few of them. Although no positively new principle may be developed, the ingenious and novel applications of old ones are subjects of constant surprise.

Therefore, endeavoring to comply with the by-law above quoted, I shall review, as briefly as possible, some of the works that have been previously commenced, were in course of construction, or actually finished during the past year.

It can scarcely be hoped to make such a record as is thus prescribed attractive or novel to those before me, most of whom are actively engaged in engineering works, but it may at least serve to refresh your memories.

The progress made in railroad construction in this country has been less than for several previous years; the number of miles of new roads built, it is stated, did not exceed four thousand four hundred, upon about one hundred and sixty-six different roads, being an average of twenty-six miles to each. This is less than in any year since 1879.

There has been considerable advance made in the rate of speed upon most of the principal trunk lines. We have to record the fastest short distance, ordinary daily travel, made in the world to the Baltimore and Ohio Road, on that part of its line between Baltimore and Washington, where a distance of forty miles is daily covered in forty-five minutes, being an average rate of fifty-three and one-third miles per hour.

A speed equally wonderful, when the long distance traveled is considered, is being daily accomplishd upon the Pennsylvania Railroad from New York to Chicago, a distance of nine hundred and twelve miles; the average running time made is a little over thirty-eight and one half miles per hour.

From a table recently published we learn that the Pennsylvania Road runs trains from New York between Germantown Junction and Philadelphia, eighty-four miles, at the average rate of forty nine and four-tenths miles per hour. The fastest English trains for about the same distance (eighty miles) are run at the rate of forty-seven and one-eighth miles per hour. Upon the French roads, for runs of about the same distance, the fastest record is forty-four and one-third miles per hour.

By way of comparison of the early and present locomotives and speed of travel, the Baltimore and Ohio Railroad, over whose tracks we have been brought to this spot, will afford a good example.

The first locomotive built in this country to carry passengers was constructed by the late Peter Cooper, and commenced running in 1830. Its weight was less than one ton, drawing one car, containing thirty-six passengers, at the rate of thirteen miles per hour.

To-day trains pass over the road of the same company between Baltimore and Washington at the rate of fifty-three and one-third miles per hour.

The last and heaviest locomotive built has just been finished by the Baldwin Works, Philadelphia, weighs about sixty-four tons, has ten driving-wheels, and a capacity to draw 500 tons up a grade of 105 feet to the mile.

Cable roads for street traffic are increasing in number, and are now in use in San Francisco, Chicago, Detroit, and Kansas City. Several lines are being constructed in Philadelphia; the general plan which originated in San Francisco in 1873, with modifications to suit the particular locality, is the one usually adopted.

The elevated road just completed in Brooklyn is, I believe, the only one of that kind finished during the past year.

The cantilever principle for long-span railway bridges is much in favor.

It is believed that the first of any prominence built upon this arrangement was erected under the direction of one of our fellow members, over the Kentucky River, on the line of the Cincinnati and Southern Railway. This has a total length of 1,125 feet, and a clear span of 300 feet, and was finished in the year 1877.

The Niagara cantilever bridge was retested during the year, and has shown remarkable immunity from changes, giving increased confidence in its stability and the correctness of the principles of its construction, which have been so fully elucidated in the interesting and valuable paper recently read before the Society by our fellow member, Mr. C. C. Schneider.

The grandest work of this character is the bridge now building over the Frith of Forth.

The construction of a bridge of twenty-two spans, two of which are of the enormous length in the clear of 1,700 feet each, is certainly a most formidable undertaking. The compression members of the spans will consist of tubes, composed of steel plates bent to form, and properly united by H-beams; they will vary in diameter from twelve to three feet. The tubular form, of course, presents no novelty of principle, it having been used in St. Louis, and other structures, but the size is unprecedented. The large piers consist of four cylinders each, of seventy feet diameter at the lower cutting edges; they are sunk by the pneumatic system. Serious difficulties have not been encountered in sinking them to the depths of sixty-eight to eighty-eight feet. No new methods are employed, and none that were not successfully used at the St. Louis and East River bridges, and are at present followed at the new bridge building across the Susquehanna at Havre de Grace for the Baltimore and Ohio Railway, differing, perhaps, only in the details of air-locks and means of removing the excavated earth, and supplying its place with concrete.

A cantilever bridge has also been completed across the St. John's River, to connect the Intercolonial railways with those of the United States. It has a clear span of 479 feet—nine feet more than that at Niagara Falls. This completes a link whereby the time between New York and Halifax can be shortened twenty-three hours, and will eventually be the means of reducing the trip from New York to Europe very materially.

The work of sinking the pier foundations for the bridge now building at Havre de Grace for the new line of the Baltimore and Ohio Railroad is being prosecuted with much vigor, and presents examples of the most advanced practice in the pneumatic method of sinking caissons. This work is, as you are aware, being carried forward by members of our society.

The Tay bridge is now being rebuilt upon improved plans and on a new alignment. The resources now at the command of our bridge-builders, modern improvements in the manufacture of steel, with more reliable knowledge of its powers of endurance and resistance, make it possible to overcome difficulties that within a few years past would have been considered, if then proposed, as almost absurd.

It is scarcely necessary to point out how much has been done to increase the security of such structures, and modify their cost, by the now very general use of improved testing machines, those belonging to the Government, and such as are owned by bridge manufacturers and others.

This society can look with satisfaction to its efforts in influencing and fostering the use of such means.

Next in order to the transport of railways over rivers comes to be mentioned the means of carrying them under the streams and through the mountains.

Of the former, the tunnel under the Mersey, between Liverpool and Birkenhead, has been carried to completion. Operations were begun in 1880. Four thousand two hundred feet of its length is under the bed of the river. It is through red sandstone, and was driven by means of the Beaumont machine. There is a drainage tunnel under the bed of the road seven feet in diameter, and a similar passage of the like diameter near the top of the main tunnel for artificial ventilation.

A tunnel for the use of the Great Western Railway, of about four and a half miles long, was commenced under the Severn in 1873. Work was carried on with but little difficulty until the drift was within about 130 yards of meeting. A large influx of water took place in 1879, thereby delaying the work, now, however, approaching completion.

The Channel tunnel, which has caused England so much uneasiness, has been driven on the British side for a distance of about one and a quarter miles, and on the French side almost half a mile. It is found by more than 9,000 soundings that gray chalk extends entirely across the Channel. Work was done mostly by the Beaumont machine, and no very serious impediments have been meet with. The water so far found is in pockets, and perfectly fresh. There is but little doubt that the tunnel could be completed for the amount estimated. Work upon it is now suspended.

The greatest achievement of modern mountain tunneling is the Arlberg, reaching from Innsbruck in the Tyrol to Lake Constance in Switzerland. Headings were commenced at both ends November 13, 1880, were pierced through November 19, 1883, and the whole completed September, 1884. Two methods of doing the work were adopted. Upon the Tyrol side Ferroux percussion air-drills were used, and on the Swiss side Brandt hydraulic boring-machine. The distance accomplished by the air-drills was 14,874 feet, and by the hydraulic machine 17,351 feet. The rock, however, on the Tyrol side was harder, and presented more difficulties than upon the other end. The work was carried on with unexampled rapidity, showing remarkable progress in the methods employed.

The following comparison with the two mountain tunnels previously constructed will show the advance made in that class of work: Mt. Cenis tunnel, seven and four-tenths miles long, cost about $376 per foot run; St. Gothard, nine and three-tenths miles long, cost about $238 per foot. The Arlberg, six and two-tenths miles long, was completed for about $180 per lineal foot.

Hydraulic wedges, consisting of rams with cutting edges, have been used successfully to force down semi-detached masses of rock in tunnels and coal-mines, to a marked extent decreasing the use of explosives.

The Metropolitan District Railway of London has constructed a new section of four miles length, much of it under the most formidable difficulties, which may be judged of by the cost, which in some parts was $120 per lineal inch run—$7,603,200.

Of the great canal projects, that of Count de Lesseps across the Isthmus has probably made as much progress during the year past as could have been expected with a work of such magnitude, and presenting so many obstructions.

The Suez Canal has almost reached its full capacity, and a large sum of money is about to be granted for enlargement.

Of the recently completed canals, the Maritime, from Cronstadt to St. Petersburg, is the most important. It is about seventeen and three-quarter miles long, and navigable for vessels drawing twenty feet. Work of excavation was mostly done by dredging machines, and has cost, including branches, over $8,250,000.

Excavation of a canal across the Isthmus of Corinth is progressing satisfactorily, and may probably be completed in another year. It is designed to be of the same width as the Suez Canal, is four miles long, and will reduce the length of voyage from the Adriatic to Turkey fully 185 miles.

Improvement of the navigation of our Western rivers by the use of movable dams has been tested fully in several cases. The Davis Island work is all completed, except the lock gates and machinery to work them. These, it is expected, will be finished during the year. It was, however, tested last summer by constructing a temporary coffer-dam across the head of the lock, which admitted a raise of the river sufficient to show doubters of its utility how great the advantages will be when completed.

Movable dams on the Great Kanawha River continue entirely successful, and have proved their usefulness on several occasions during the past year.

It is believed that probably the earliest application of movable dams for maintaining the water level of rivers was made by Mr. Josiah White, who patented the so-called "bear-trap" dam, an ingenious automatic device, and erected twelve such in 1819 upon the Upper Lehigh and its tributaries.

A similar dam to these is now proposed to be built on the Kentucky River at Beattyville. It is gratifying to find the words given below in the report of the United States Engineer for 1884:

"Jetties of the South Pass of the Mississippi have maintained the full depth and width of channels required by law during the year embraced by this report."

This is certainly a full and ample acknowledgment of the very valuable work accomplished by our fellow-member, Captain Eads.

The stupendous project for building a ship railway across the Isthmus, proposed by this distinguished engineer, has been so fully explained and clearly described by the papers recently read before the society by Mr. Corthell as to make any further mention unnecessary.

Methods of transporting earth when combined with water have been extensively employed under the charge of the United States Engineers at Oakland, opposite San Francisco. The sand under the surface is worked loose by a species of submerged plows fixed upon the lower end of a revolving tube, through which the sand and water are raised by a centrifugal pump and delivered through pipes to any point required. It is found, under favorable circumstances, as much as forty per cent. of solid matter can thus be delivered at a distance of 2,800 feet from the dredging machine. Sixty thousand cubic yards were delivered in this manner to a distance of 1,200 feet in one month, at a cost of from five to six cents per cubic yard.

The water-jet has been used in many cases during the year in sinking piles and similar work. An experimental trial has been recently made to deepen parts of New York Harbor by means of a hydraulic injector-jet, with some prospect of success.

The most extensive and important work for the water-supply of a city is that upon the new aqueduct tunnel from the Croton dam. Considerable work has been done upon the shafts and tunnel between the dam and High Bridge. It is a work of great magnitude, and is being conducted with all the engineering ability that can be brought to bear upon it.

The next work of importance for similar purposes is the tunnel being constructed for the increased supply of Washington city. It will be about 20,750 feet long, through rock. Compressed air is used, not only for the drills, but for hoisting, pumping, and ventilating. Air from the compressors is carried overground through five miles of pipe, which will finally be extended to ten. This tunnel was commenced November, 1884, and is expected to be finished during the present year. In connection with it the dam at Potomac Falls will be raised, and a distributing reservoir of large capacity be built.

The works for the supply of Baltimore, which some of you have had the opportunity of examining, have also a conduit in tunnel of seven miles in length; five years were occupied in its construction; it is twelve feet in diameter, and carries the water from the dam to the receiving reservoir. These works, with their white marble dams, large storage and distributing reservoirs, are now considered among the most complete and satisfactory in the country.

This may almost be said to be an age of tunneling. In this brief record we refer to three mountain tunnels, Mt. Cenis, St. Gothard, , and Alberg; three water-supply tunnels, Baltimore, Croton Aqueduct, and Washington city; three sub-aqueous tunnels, Severn, Mersey, and British Channel.

It is scarcely necessary to say that the use of compressed air for power and ventilation, hydraulic machines, and high explosives, has made practical works of this character that would formerly have been impossible.

Thorough and extensive surveys are now being made by the Water Department of the city of Philadelphia, and gaugings and rainfall data being obtained, with the object of ascertaining the most feasible plan for increasing and improving the water supply to the city.

The subject of maintaining the purity of the sources of water supply is now demanding serious attention. There are many points not yet fully understood, or satisfactorily accounted for, notably the cause of water becoming foul in deep storage-reservoirs, as at Baltimore, Reading, and other places.

The analysis of water is still, to some extent, a doubtful process. A thoroughly reliable standard of absolute purity and wholesomeness has apparently not yet been agreed upon or made known by those engaged in investigation of the subject.

A method of oxidation of the impurities in water, by forcing air at high pressure through it in the ascending mains and reservoirs, has within the year been tried at the works from which Hoboken receives its supply; it is claimed to be successful. Apparatus is now being put into use for the same purpose at three of the pumping stations of the works at Philadelphia.

The advantages of aerating water by passing over dams and obstructions has long been acknowledged. Arrangements were introduced at Belmont Works, Philadelphia, in 1872, to expose the water discharged from the pumping main to the action of the air, by passing it over three weirs and down the sloping banks of the reservoirs. If the same object can be accomplished, and more rapidly, by the method above mentioned, it will be an important point gained.

Dr. Angus Smith experimented in 1882 on the effect of forcing air through sewage, and showed conclusively that "water saturated with air was no longer liable to putrefaction."

Knowledge of the amount of rainfall available from drainage areas has received much valuable addition

from careful and extended observations of those engaged upon the surveys for the supply of New York, Boston, Philadelphia, and other large cities.

There is now in England a society called the "British Rainfall Association," the object being to put up as many proper rain-gauges as possible upon drainage areas and elsewhere. It numbers over 2,000 intelligent observers.

The importance of such records can be fully appreciated by those of our members who have been called upon to study the important bearing of such determinations upon water-supply from gathering grounds, and the maintenance of the navigation of our rivers.

Public supply of hydraulic power has been in use in Hull, England, since July, 1882. The system is now being introduced into London. Mains for the purpose are laid upon both sides of the Thames, from Blackfriars to London Bridge. These are kept supplied by triple-cylinder compound pumping-engines, through an accumulator, under pressure of fully 700 pounds to the square inch.

Power thus produced is utilized on both banks of the river by cranes, elevators, and driving machinery. One of the most useful of its functions is an ingenious arrangement for increasing the efficiency of water-supply during fires. By means of a so-called "injector-hydrant," water taken from the ordinary supply mains at a pressure of about thirty pounds to the square inch can be made to deliver 150 gallons per minute through a 1-inch nozzle to a height of over 80 feet, with a consumption of about 24 gallons from the main under high pressure.

The advantage of such a system, available at a moment's notice, upon the docks, and in neighborhoods where valuable storehouses are situated, can readily be seen.

Compressed air has also been supplied to the public in several cities of Europe, applied to production of power for small machines, the transportation of parcels through business establishments, and for postal and telegraphic purposes, by a somewhat similar arrangement to that which has been some time in use by the Western Union Telegraph Company in New York.

One of the most important developments of the year is the utilization of natural gas for fuel in manufactures and for domestic use. By its employment it has been found that a cleaner and better grade of iron and steel made by the Siemens open-hearth method has been produced than by the use of coal.

A novel use of compressed carbonic acid gas was made at the Krupp Works. Gas is admitted under very high pressure over the steel in moulds during its solidification, thus securing perfect castings.

This gas is now supplied commercially in Germany compressed to a liquid state in iron bottles. In Berlin it is now used by the steam fire-engines as motive power, enabling them to do service before getting up steam.

Much attention has been paid to sanitary engineering, but the best system of disposing of sewage and the merits of separate or combined systems of sewers are still mooted questions. The latter can probably be best decided by the topography and local conditions of the place to be drained.

An exceedingly ingenious method of sinking shafts through quicksand employed in Europe deserves mention. The whole mass surrounding the shaft was frozen solid by sinking pipes around its sides by means of sand-pumps; into this was forced a freezing mixture. By this means a space 24x27x18 feet deep was frozen in thirty days, the shaft sunk and walled up without damage or danger to those employed.

In telegraphy, the Delaney multiplex method of passing as many as seventy-two messages over one wire has been developed in the year, and is in practical use between Boston and Providence.

The Phelps system, whereby messages may be transmitted to and from rapidly moving trains, bids fair to be one of the most important and useful applications of telegraphy invented.

The electrical exhibition held in Philadelphia last year afforded an excellent opportunity to study the rapid strides being made in that branch of engineering. Exhaustive tests have been and are still making by the Institute upon the duration of incandescent lights, and to determine the economy and efficiency of the dynamos and kindred apparatus submitted for the purpose.

I think we may look forward to the use of electricity as motive power on our railroad trains, probably applied to every pair of wheels upon the entire train, thus dispensing with the excessively heavy locomotives of the day, to the great advantage and reduced cost of the bridges and roadbed.

Considerable improvement has been made in the duty performed by water-works pumping-engines, much rivalry being exhibited by several builders.

Compound engines have in all cases been adopted, mostly with horizontal steam and pump cylinders.

The time-honored Cornish pumping-engine is now almost entirely abandoned, even in conservative England.

Duties ranging from 84,000,000 to 105,000,000 foot pounds with 100 pounds of coal have been claimed upon trial tests.

Some of the most powerful and successful pumping-engines are those employed upon "oil-pipe lines." They are of the Worthington compound duplex type; the work performed is exceedingly severe, the requirements in many cases being the delivery of 15,000 barrels of crude oil per day, frequently under a pressure equal to a head of 3,500 feet, the engines being required to run day and night throughout the year. Engines of this class were ordered from and sent to England by Mr. Worthington, for the purpose of forcing water through a pipe-line across the desert, but the withdrawal of the army from Egypt made them unnecessary.

TRIPLE SHIPS.

MR. WILLIAM COPPIN, writing to *Engineering*, says: Having had a long experience in the construction of ships after the present type, and having also, by models, tried many experiments to obtain the highest speed, I have designed and patented a triple-hulled ship, which I believe will be the ship of the future. By having three hulls instead of one, I have been enabled to reduce the angle of resistance to the lowest minimum. The center hull (see engravings) is shorter than the outside ones, and as at each end of this central hull there is a full-power propeller worked by two sets of compound engines, with boilers quite independent of each other, it is evident that this provides against any accident, and brings the propelling powers from the end (old arrangement) nearer to the center. In a heavy sea, always dangerous, this plan prevents the racing of the engines.

The speed, as well as cargo capacity, of this plan of vessel can be regulated to suit any trade that she may be intended for, but if for mails and passengers only, the rate of speed may be 27 knots per hour; this speed I have proved in a small test boat 37 ft. long across a river in smooth water, propelled by a sail.

I have found by experiments that for a ship to move through and displace her cube of solid water, her lines, equally at both ends, must be very fine, and as the furrow produced by the ship's movement fills upward, I have found that the semicircular section of floor or bottom is the best form for high speeds, allowing, as it does, the displaced water to return freely, which is not the case with a flat-floored ship, as will be easily perceived. Such a displacement by my triple ship with a given power produces a much higher speed than can be attained by a single ship. In addition to this the triple ship is a perfect lifeboat in herself, and because of her peculiar form is unsinkable.

The advantages I seek to combine in one vessel are perfect safety, comfort against rolling, high speed, and great stability. The public do not enjoy this at present.

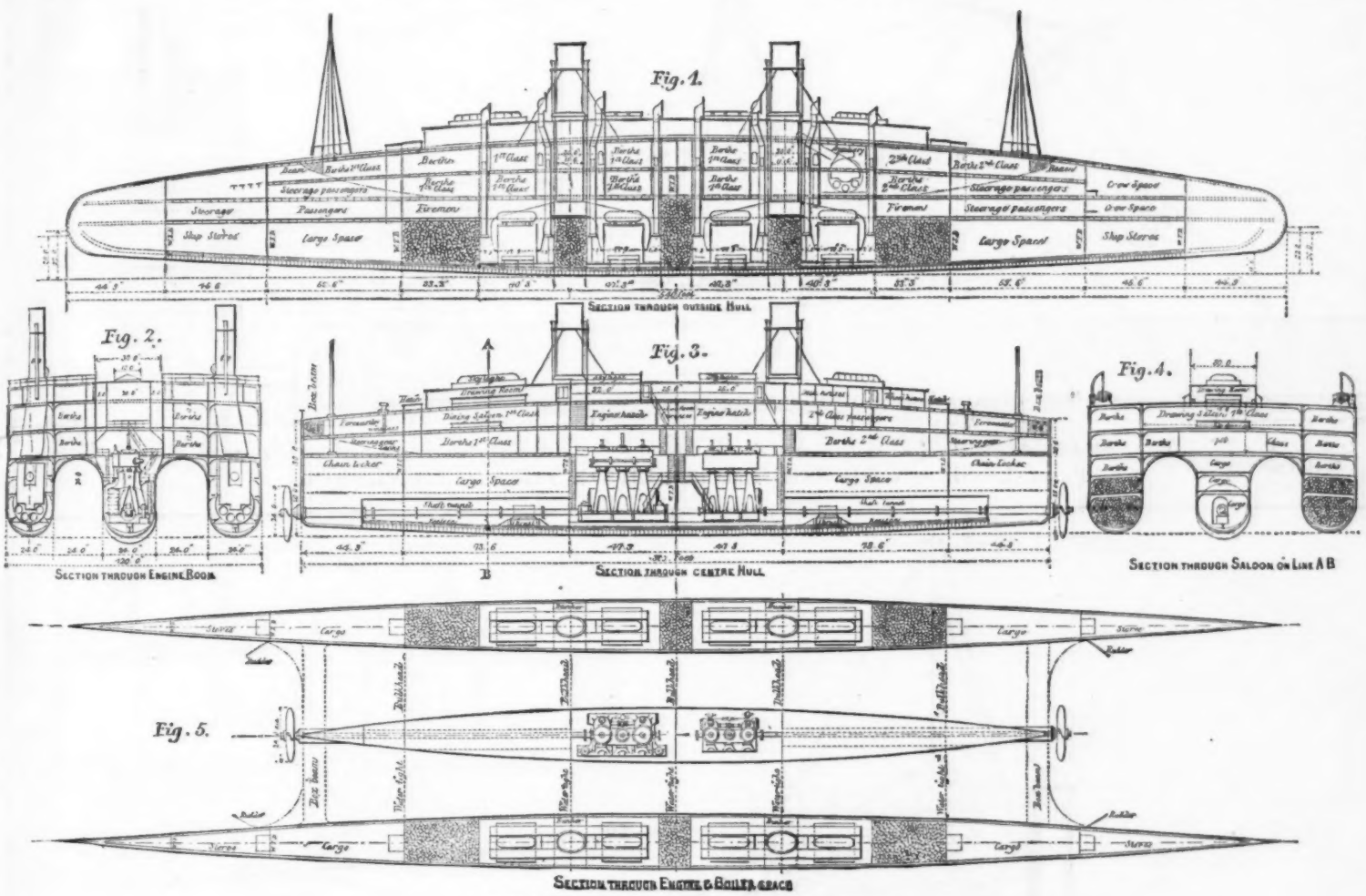
AMERICAN DREDGERS AND EXCAVATORS.

THE different styles of dredging machines employed in America are the chain and bucket, spoon, suction, and hinged bucket.

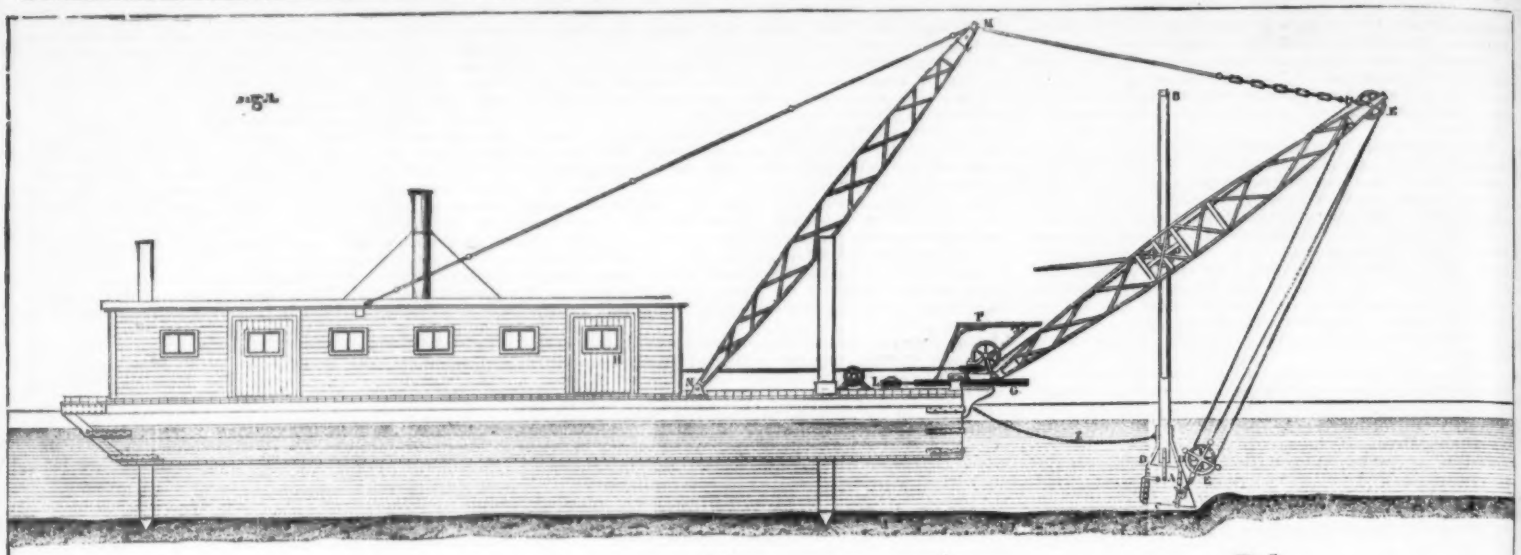
Chain and bucket dredgers are the ones most used in France, although the spoon and hinged bucket ones have been used here in recent years. So we have thought that it would not be of interest to dwell in this place upon a description of apparatus that is now well known to engineers. Suction dredgers have also been used in France, at Dunkirk, Saint Nazaire, and Boulogne, and in none of the apparatus that we saw in America did we find any improvements upon the French ones. We shall limit ourselves to a description of the most improved spoon dredge that we met with, and of a chain and bucket dredge of great power.

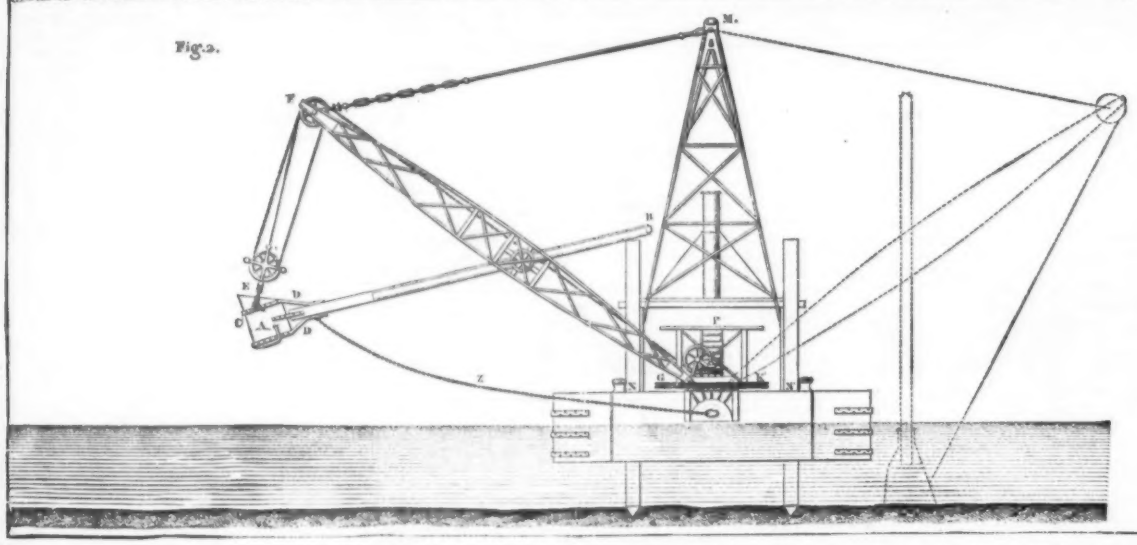
The Montreal Spoon Dredge.—The spoon dredge just mentioned is employed upon the Saint Lawrence River at the port of Montreal. It is represented in the accompanying engraving (Plate I.). A spoon, C, is fixed at A, by means of a joint, to a shaft, AB. Two arms hinged to the extremity of the spoon are capable of being affixed to the shaft, AB, in different positions by means of bolts, so as to permit of regulating the inclination of the spoon with respect to the shaft.

The spoon is of iron plate. It is cylindrical, has a steel cutting edge, and is of nearly four hundred and forty gallons capacity. The bottom opens through the unfastening of a catch, and closes of itself when it falls back upon the spoon. The spoon is suspended by eyebolts from a pulley, E, by means of which it is lifted. The lifting chain runs over a pulley, F, placed at the extremity of the crane, FG, then over a pulley, E, and afterward over another pulley, F, and finally winds round a windlass in the maneuvering cabin, H. The crane, FG, is of iron plate, and rests upon and is hinged at G to a wheel, K, which is movable around a vertical pivot. By its extremity, F, it is suspended at M to a frame, MNN'. This latter, which also is of iron plate, is fixed to the boat by a joint at NN', and is held at its extremity by a tension rod, likewise fixed to the boat, and which must be so regulated that the point, M, shall be situated in the prolongation of the vertical axis passing through the point, G. Nuts upon the tension rod,



COPPIN'S TRIPLE STEAMSHIP.





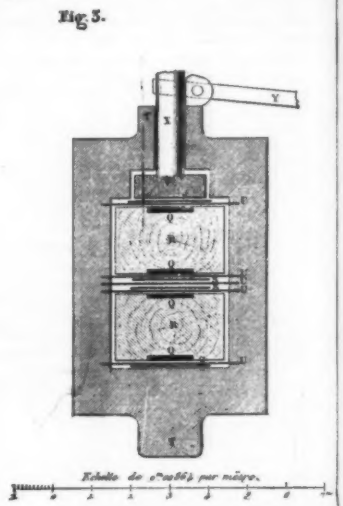


FIG. 1.—Longitudinal Elevation. FIG. 2.—Transverse Elevation. FIG. 3.—Mode of tightening the shaft of the spoon.

PLATE I.—SPOON DREDGE EMPLOYED ON THE ST. LAWRENCE.

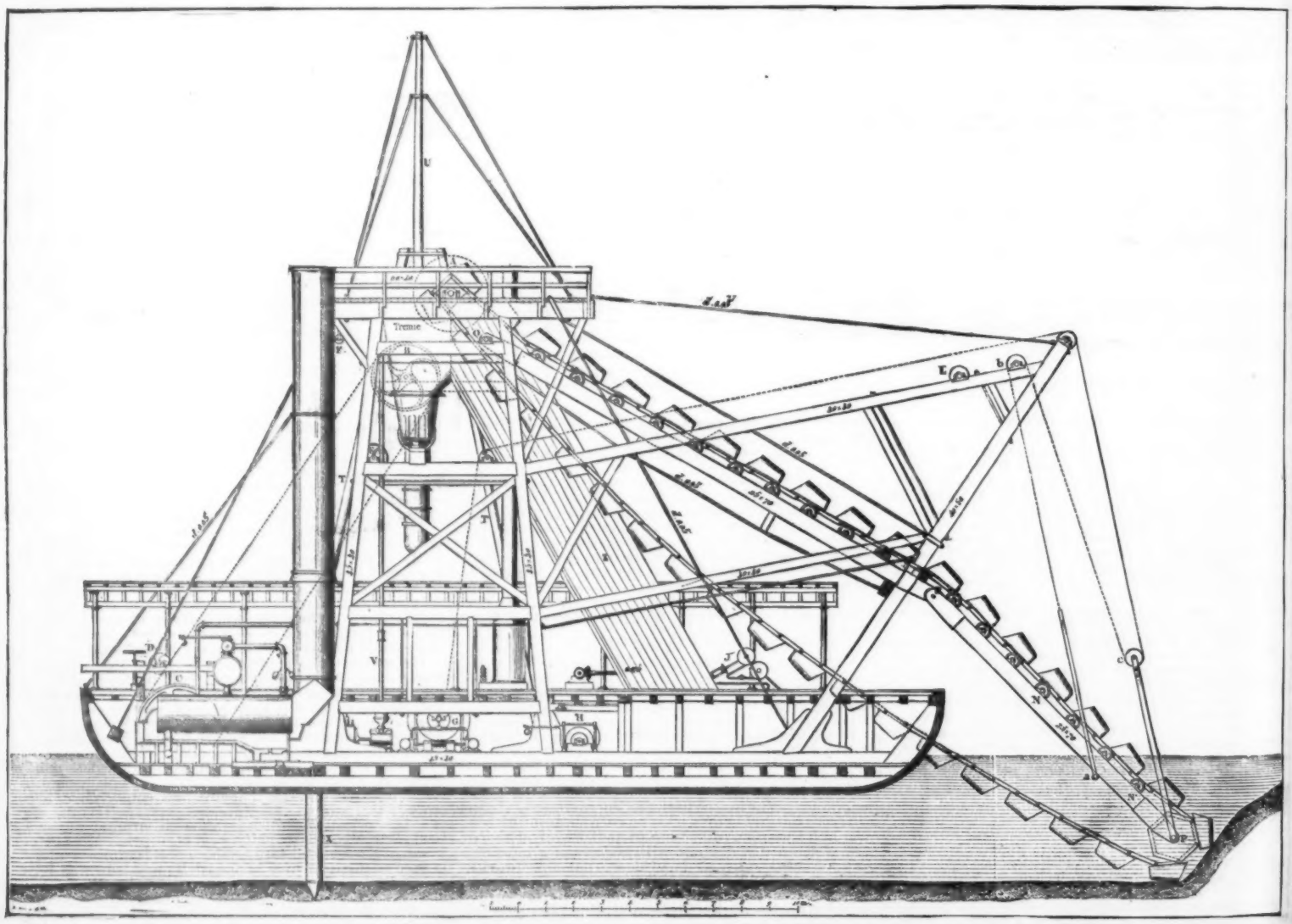


PLATE II.—HERCULES DREDGE.—ELEVATION AND LONGITUDINAL SECTION.

FM, permit of varying the inclination of the crane, FG. Round the wheel, K, runs a chain which is set in motion by an engine located upon the deck and maneuvered by the engineman in the cabin, H. A platform, P, for a workman to stand upon, is fixed to the wheel, K.

The shaft of the spoon is formed of two pieces of wood, which are shown in section in Fig. 3, at RR. Into the sides of each of these are set steel plates, Q; and other steel plates, S, are fixed to each extremity. At O the shaft is connected with a frame of cast iron, which is shown in section in Fig. 3. This frame rests, through the bearings, T, upon pillow blocks affixed to the crane, FG. Five steel plates, which are capable of sliding laterally in the frame, are placed in the intervals left free between the plates, S, and the uprights to which they are attached. A movable piece, V, actuated through the intermedium of the cylinder, X, and a lever, Y, maneuvered by the workman on the platform, P, permits of compressing the beams, RR, and the steel plates. The great surface of contact thus obtained between the shaft of the spoon and the frame renders these two pieces interdependent, and the shaft can then rotate around the axis of the frame only. When, on the contrary, the piece, V, is carried backward, the shaft of the spoon slides in the frame with entire freedoom.

In order to complete the description of this dredge, it remains for us to add that a chain, Z, affixed to the shaft near the spoon, permits of pulling the latter backward. This chain winds around a windlass maneuvered by the man in the cabin, H.

In order to dredge, the boat is first brought to the desired position, and fixed in place by lowering the anchor posts, N and N'. The engineman in the cabin, H, brings the crane opposite the place to be dredged, through a rotation of the wheel, K. He then disengages the windlass that actuates the lifting chain; and the workman at P, keeping the lever, Y, locked, the shaft revolves through its own weight around the axis, O. This motion may be regulated and moderated by means of a brake. When the shaft reaches a vertical position, the workman at P frees the lever, Y, and the spoon drops to the bottom. During this time the engineman has thrown the chain windlass into gear, and regulated the length of the chain in such a way that the spoon is carried backward slightly when it reaches bottom. The lever, Y, is then locked anew. The engineman disengages the windlass of the lifting chain, and the spoon, describing an arc of a circle around the point, O, becomes filled. When the man at P judges that the spoon is full, he lets it right itself by ceasing to act upon the lever, Y, but he takes care to lock this lever again when the length of the shaft beneath the frame is what it ought to be, in order to have the spoon place itself over the point where the excavated material is to be deposited. During this time the engineman sets the wheel, K, in motion, in order to bring the crane and spoon over the place of deposit. He arrests the motion of the lifting chain and that of the wheel, K, when the spoon has reached the desired height and position. Then the workman at P, by means of a rope, pulls the catch that holds the bottom of the spoon, and the latter empties.

This dredge differs from the older ones that we have seen, in two arrangements: 1. In the old spoon dredges the crane is of wood, and is formed of inclined pieces connected by diagonal ties, with uprights placed upon the axis of rotation. In the example just cited the crane consists of an iron plate truss, the vertical axis is reduced to two trunnions, and its upper part is connected with the boat by two pieces which distribute the stresses that it has to support toward the center and stern of the boat, and which tend to make the latter plunge forward. This permits of increasing the length of the sweep, and consequently the distance to which the spoon is capable of dredging. With this machine it is possible to dredge to a horizontal distance of nine yards from the axis of the crane, and to reach depths of ten yards under water. 2. In other dredges, motion of the shaft is secured either by means of a chain whose two ends are fixed to its two extremities, and which winds round a windlass placed upon the crane, or by means of racks fixed upon its sides and actuated by cog-wheels. In both cases the workman in front must act upon a wheel in order to cause the shaft to rise and descend. In the apparatus just described the maneuver is simpler and more rapid.

The "Hercules" Bucket Dredge.—Chain and bucket dredges have never been much employed in America, yet we saw several upon the Saint Lawrence, where the circumstances were such as to render the use of them advantageous.

A few years ago a dredge of great power was employed for excavating a canal across Union Island, near San Francisco. This excavated a canal nearly three miles long, 80 feet in width, and 12 feet in depth, in 22 days of eight hours work each.

Three dredges of the same type have been constructed for work on the Panama Canal, but the power of these is one and a half times that of the Union Island machine. These dredges bear the name of "Hercules," and were designed by Messrs. H. B. Angell and H. H. Lynck, who have taken out a patent for their invention. Plates II. and III. represent one of these machines.

The length of the boat is 100 feet, and its greatest width 60 feet. There is a channel in the center, for the passage of the bucket ladder, 36 feet in length by 6½ in width. The boat is of wood covered externally with yellow metal.

The bucket ladder is divided into two hinged parts, the upper one of which is 60 feet in length, and the lower 40. The upper joint, Q, of the ladder and frame is formed by an axis 6 inches in diameter, the intermediate joint, R, is formed by an axis 7 inches in diameter, and the joint of the ladder and lower tumbler, P, has an axis 8 inches in diameter.

With this arrangement it is necessary to maneuver only sixty feet of the bucket ladder, instead of a ladder one hundred feet in length, which would be very heavy. The upper part is generally fixed to the frame, but it may be moved slightly by means of a chain running over the pulley, L, and actuated by the engine, J. The lower part is raised by a chain fixed at *a* to the ladder through the intermedium of an iron stirrup. This chain passes over the pulley, *b*, and then over the pulley, *c*, which is attached to the tumbler, P, through the intermedium of an iron stirrup, then over the pulleys, *d* and *e*, and winds round a windless actuated by by the engine, G. The buckets are 38 in number, and have a capacity of 35 cubic feet each. They are made of half-inch boiler iron, and are attached to the chain by angle irons that are riveted to them and simply bolted to the chain, so that the buckets may be easily replaced. The links of the chain are each 36 inches in length, and alternately simple and double. The simple ones, which carry the buckets, are 8 inches in width and 1¼ inches thick. The double links are 6 inches in length and 1 inch thick. The axes that connect the links are ¼ inch in diameter.

In the ascending motion, rollers placed upon the chain bear against the upper surface of the bucket ladder.

The hopper into which the material is poured is made of strong boiler iron. It flares slightly at the upper part, and has a diameter of 5½ feet at the point where it connects with the large chute. This latter, which also is of boiler iron, is coupled with the hopper by an elbow. It is cylindrical, and is 150 feet in length and 3 feet in diameter. It is suspended by a series of wire cables, 1 inch in diameter, from a mast, U, fixed to the upper part of two inclined masts, T T'. Mud of slight consistency can slide in the chute without the addition of water, but, for compacter material, water has to be added to facilitate its passage. For this purpose there are two pumps, which force water into a pipe, V, 7 inches in diameter, that may be made to debouch either into the elbow of the chute or into the upper part of the hopper.

The motion of the bucket chain is effected by means of two steam engines of 100 horse power each, which actuate the wheel, C. This latter transmits its motion to the wheel, B, through the intermedium of a belt, and this wheel, B, moves the upper tumbler, A, through the intermedium of a double gearing which is seen in Plate III. The diameter of the pulley C is 10 feet, and that of B 8 feet. Each is 3 feet in width. The axle of the tumbler, *a*, is 10 inches in diameter, and 17 feet in length.

The engines, G, which actuate the chain that raises the lower part of the bucket frame are two in number, and of 40 horse power each.

At H are located two other engines (40 horse power each), which serve to move the anchor posts, X and Y, and to actuate the two small windlasses, M M, round which wind the chains that serve to fix and move the dredge.

At J there are located two other 40 horse power engines, which serve for removing snags or stones by means of chains passed over pulleys—one of these latter being seen at K in Plate III. These engines may

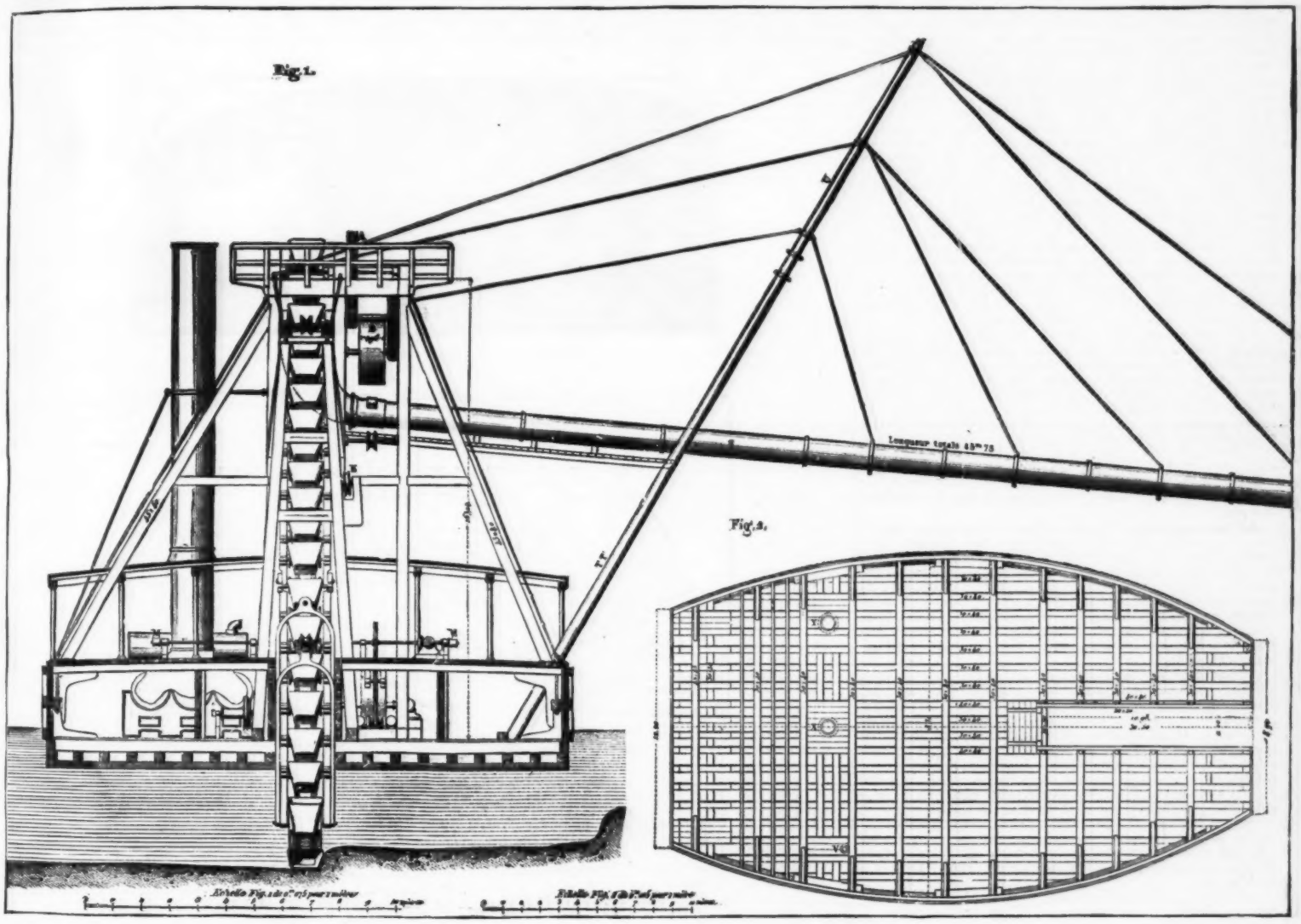


FIG. 1.—Elevation and transverse section. FIG. 2.—Plan.

PLATE III.—HERCULES DREDGE.

also be used for moving the upper part of the bucket ladder, as we have just explained.

The two anchor posts, X and Y, are of oak, and terminate beneath in cast iron shoes. A wooden chute, Z, extends from the hopper to the channel in the boat, through which the bucket and frame pass. It is composed of planks two inches thick at the sides and three inches thick at the bottom, covered with iron plate. The object of this is to protect the deck and engines against material falling from the buckets, and also to guide the descending buckets.

The dredging is performed over an arc of a circle having its center at X. During the dredging, the anchor post, X, is raised, and a lateral motion secured by four chains that wind round the windlasses, M, and the two first of which pass over pulleys attached at N N^1 to each side of the bucket ladder, and are then affixed to the banks, while the other two pass over pulleys attached to each side of the deck, upon the line, X Y, and are then fastened to the banks.

To move the dredge forward, the anchor post, Y, is lowered at the moment the front of the dredge bears to the right. Then X is raised, and the boat is given a motion from right to left until X, after describing an arc of a circle whose center is at Y, returns to the axial line of the channel to be dredged. Then X is dropped and Y is lifted, in order to begin the dredging again.

It takes seven men to maneuver the machine—a captain, an engineman, a stoker, and four assistants. It requires certain maneuvers on the banks also in order to place and remove the chain fastenings.

The quantity of material dredged naturally depends upon the nature of the ground. We may estimate the dredge's work by supposing that the buckets fill completely, and thus obtain a maximum of its power. The wheel, C, is capable of making 60 revolutions per minute, thus causing the tumbler, A, to make 9. Now, at each revolution of the latter, 2 buckets pass, or 18 per minute. According to our hypothesis, then, 930 cubic feet would be dredged per minute. Supposing that the time taken to move the dredge was $\frac{1}{10}$ that of the work, and that the day's work was of 10 hours, the daily cubage would be 540,200 feet. But it is very certain that the buckets will never be full, and it is probable that the maneuvering of the boat will absorb more than $\frac{1}{10}$ of the time, and the above figures, then, are notably exaggerated. It is, nevertheless, certain that a dredge like this is capable of doing a very large amount of work, and a much greater amount than any machine that has ever hitherto been constructed.

We shall now compare the different systems of dredges used in America, and see under what circumstances each may prove advantageous.

Advantages of the Bucket Dredge.—The bucket dredge has a continuous motion that permits of the best utilization possible of the motive power. If, then, the work to be done is uniform, regular and important, that is, if it is a question of dredging in calm water a vast extent of earth that presents a uniform and quite feeble resistance, the bucket dredge is preferable to the other systems. The example of the St. Lawrence work is a proof of this. Here, with buckets of 18 cubic feet capacity, dredging was done at a cost of $\frac{1}{4}$ cent per cubic foot, a cost still lower than that of the dredging on the river Clyde, which amounted to $\frac{3}{4}$ cent, carriage not included.

Advantages of the Spoon Dredge.—The spoon dredge has the following advantages over the bucket: It is better adapted for use where the nature of the cutting is complicated, and where ships and other obstacles are present. By a proper direction given the spoon and its shaft, the action of the former may be rendered more efficacious, and its filling more complete in soil whose disintegration is difficult. The maneuver is surer, the parts are simpler, breakages are less frequent, and repairs are easier.

Advantages of the Hinged Bucket.—The dredge with hinged bucket has parts that are still simpler than those of the spoon dredge. In dredging vertically it is capable of reaching great depths without losing its stability. It is capable of working in unprotected roadsteads—something that cannot be done by machines of the two other systems—and it does not need to be anchored, and so does not incommode ships in port. But it is adapted only to important and continuous dredging, and not so well as the spoon dredge to irregular work. Its action is not very efficient in earth of considerable resistance. When used under circumstances that are favorable to its operation, it performs the work more economically than the spoon dredge does.

Suction Dredges.—These may be employed with advantage for dredging performed where the bottom consists of liquid mud or fine sand.

Cases to which Each System is Adapted.—In short, it may be said that it is well to employ the chain and bucket dredge in important and regular works, in sheltered and free localities, and for earth whose resistance is not great; the hinged bucket dredge in important and continuous works, in places that are not sheltered or are occupied by vessels, and for earth of slight resistance; the spoon dredge in works of little importance, in irregular dredgings, and for earth of great resistance; and the suction dredge in the particular cases of liquid mud or fine sand.—*G. Cadart, in Ann. des Ponts et Chaussees.*

IMPROVED CALCULATING MACHINE.

AN ingenious calculating machine is to be seen in the Inventions Exhibition, London, at the stand of its inventor, Mr. Joseph Edmondson, of Halifax, Yorks. Fig. 1 is a perspective view and Fig. 2 a plan of the apparatus as presented to the operator when seated in a position for working it. The principle of this machine is very simple. Beneath each number slide are two radial axes, one above the other. The lower one makes one revolution for each revolution of the motive handle, and has upon it a cylinder. That half of the cylinder which is farthest from the center of the machine is devoted to reckoning, and the other half to stopping and locking the axis above it, until the moment when the reckoning half, or reckoner, begins to operate. The reckoner is again divided into ten sections, on which there are respectively 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9 teeth, and a considerable blank space; the section with nine teeth being the farthest from the center of the machine. The eight teeth of the next section are a prolongation of an equal number of the teeth of the preceding; and so on for each section; so that to the eye the reckoner presents a series of successively decreasing teeth, and from its stepped appearance it may be termed a stepped reckoner. The stopping or locking half of the cylinder is also stepped to correspond with the stepped reckoner. On the upper axis is a tube, free to slide longitudinally, and having a key fitting into a groove in the axis. The tube carries at its outer end a pinion of ten teeth gearing with the stepped reckoner, and at its other end a star wheel of ten rays fitting the stepped stop. A fork projecting below the number slide fits into a groove round the tube, so that the motion of the number slide is communicated to the tube, whose pinion is thus placed in position to gear with that section of the reckoner the teeth of which correspond in number with the figure in front of the curved rule. The pinion and star wheel are at such a distance apart that the latter is always upon the section of the stepped stop corresponding to the section of the reckoner with which the former is placed to gear.

On the lower axis, and nearer to the center of the machine, is a piece movable longitudinally, but carried round with the axis by a pin fitting into a hole at the end of the stepped stop. It is composed of the secondary carrying tooth and its corresponding stop, there being an incline on the inner edge of the latter, the use of which will be presently explained. Just above this movable piece there are, fixed on the upper axis, a second pinion of 10 teeth and a star wheel. The pinion is so set that when the piece below it is close up to the stepped stop, the secondary carrying tooth passes it by; but when the piece is moved inward, this carrying tooth gears with the pinion, and, when revolving, moves it one tooth forward. As soon as this has taken place, the incline comes in contact with a pin in the frame of the machine, which pushes the piece into its former position. Under the disks on the circle, the before mentioned upper axis carries two reversed bevel wheels of 10 teeth each, on a tube free to move longitudinally, but carried round by a key fitted into a groove on the axis. These wheels are moved longitudinally by the regulator, as may be seen by taking off the circle. Between them (and in gear with one or other of them, according to the position of the regulator) is a similar bevel wheel on the spindle of the corresponding number disk, and above the wheel is the primary carrying tooth. As the pinions and the bevel wheels have each ten teeth, and the number disk has ten figures, every tooth which the pinions are moved counts one, either forward or backward on the disk. When the figure in the aperture on the disk passes from 9 to 0 in addition, or from 0 to 9 in subtraction, the primary carrying tooth passes the wedge-shaped end of the upper arm of the carrying lever, which it pushes back. This carrying lever moves on a perpendicular axis. Its lower arm clutches a pin in the shaft of a fork under and parallel with the lower axis beneath the next higher number slide. This fork fits into a groove around the movable piece of the secondary carrying tooth, which it shoots inward into position for adding or carrying 1 as above described.

Each lower axis is timed to operate on the pinions above it, at least one tooth later than its neighbor to the right, to allow time for the latter to shoot the carrying tooth. This is not the case, however, with the axes under the lowest number slide but one, and the index slides, B and C, which are all timed to act simultaneously with the lowest number slide. It will be seen that each revolution of the motive-handle, and consequently of the reckoners, causes the latter to move the pinions above them as many teeth as there are on the sections of the reckoners, over which the pinions are respectively set by the number slides. This motion of the pinions is communicated to the number disks, and therefore adds or subtracts accordingly.

This machine, we understand, will work the four fundamental rules of arithmetic with absolute correctness. In the multiplication and division of large numbers, as well as in the combined operations of multiplying and adding, or of multiplying and subtracting, it effects a great saving of time and brain power. Any number under a hundred millions can be multiplied by any number under a million millions. The result when the highest numbers within these limits are employed is a product of twenty figures, the time taken (after the figures are set on to the machine) being two and a quarter seconds, on the average, for each figure of the multiplier. It therefore forms an invaluable adjunct to offices and individuals having extensive calculations to deal with.—*Iron.*

ON THE PURIFICATION OF WATER BY IRON ON A LARGE SCALE.

By W. ANDERSON, M. Inst. C. E.

IN January, 1883, in a paper on the Antwerp waterworks read at the Institution of Civil Engineers, I described the application of Professor Bischof's method of filtration, through a mixture of spongy iron and gravel, to the purification of the waters of the river Nethe. The eighteen months' additional experience gained has shown that, so far as the purification of the water is concerned, Professor Bischof's process leaves little to be desired; but the working of the system has been costly, and the area of land required, as well as the quantity of iron necessary, has, in the case of the Antwerp water at any rate, proved very much beyond the inventor's expectations. The increased demands of the town rendered it necessary to extend the arrangements for purifying the water, and it became my duty to advise the directors of the company on the best means of doing this.

The extension of Professor Bischof's method would have involved so great an outlay that after trying, unsuccessfully, many experiments on direct filtration through unmixed iron at high rates of flow, I determined to adopt a plan first suggested to me some years ago by our chairman, Sir Frederick Abel, of agitating the water to be purified with iron instead of attempting to filter it. The object, in either case, was to expose the water as much as possible to an extended surface of iron; consequently, any plan by which the iron could be made to keep itself clean by rubbing against itself continually would seem to be a more rational way of attaining this object than of trusting to a partial filtration through a more or less spongy material. The obstacle to trying Sir Frederick Abel's method at a much earlier date was the belief entertained by Professor Bischof that a contact of about forty-five minutes was necessary to insure complete purification, and any such time would be fatal to mechanical means of performing the work. The late Professor Way and Mr. Ogston, it is true, had shown that with very finely divided iron the effect was much more rapid, but there was still a doubt about its permanence. In the autumn of last year a revolving cylinder, 4 ft. 6 in. in diameter and 5 ft. 6 in. long, was adapted

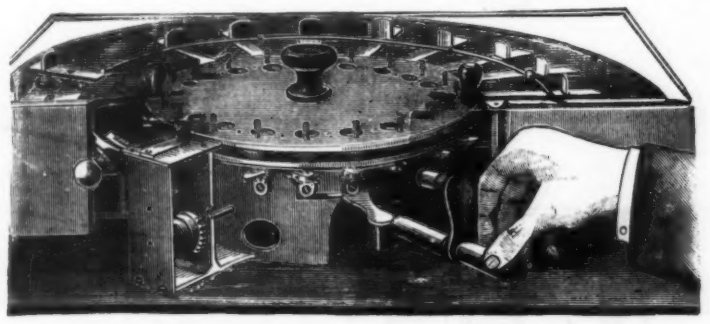


FIG. 1.

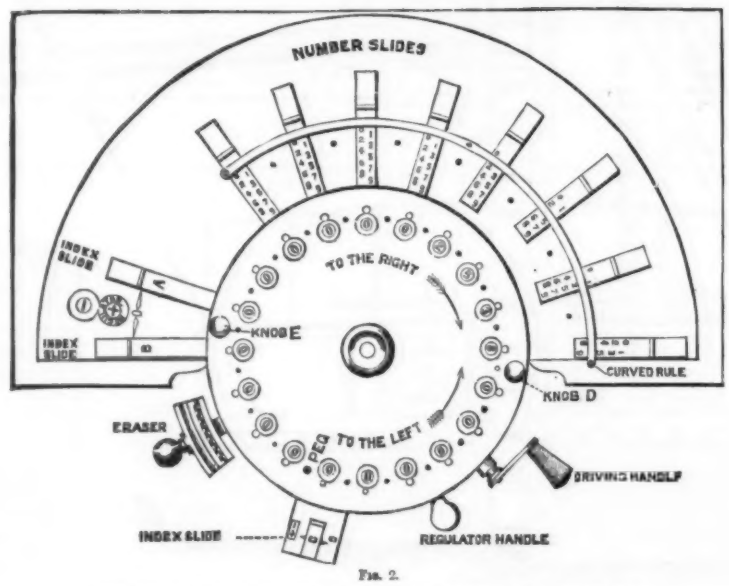


FIG. 2.

EDMONDSON'S CALCULATING MACHINE.

to try Sir Frederick Abel's system. It was fitted with inlet and outlet pipes, and with shelves or ledges for scooping up the iron, raising it to the top of the cylinder, and then letting it fall through the water. At first I began to run water through at twelve gallons per minute, which gave a contact of about forty-five minutes, but I found that at this rate the water was very heavily charged with iron. I gradually increased the quantity to thirty gallons per minute, and then found that 1·20 grains of iron were dissolved per gallon, or about twelve times more than experience at Antwerp showed to be necessary.

The flow was increased to sixty gallons, and even then 0·9 grain per gallon was dissolved. The experiment looked so hopeful that I fitted much larger pipes to the apparatus, and having made some other dispositions connected with maintaining a uniform distribution of iron in the cylinder, and preventing it being washed away by the comparatively rapid current that would be possible, I sent the "revolver," as it came to be called, to Antwerp, where it was put to work at the end of last February, and has continued to operate ever since. The head available for forcing the water through the "revolver" is, at Antwerp, limited to 5 ft., but by fitting very large pipes I have managed to get 166 gallons per minute through; this gives a contact of about 3½ min., and is so amply sufficient that I feel sure that, even for the waters of the Nethe, much less time will be adequate. The charge of iron is about 500 lb., and the quantity taken up by the water, including impurities and very fine iron washed away, during a run of thirty-three days, was 0·176 grain per gallon.

By making suitable arrangements, and choosing a favorable time with respect to the demands of the town, we were able to obtain samples of water that have been purified by the "revolver" only; and after proper exposure to the air, followed by filtration through one of the large sand filters, the result obtained has been that the color was very little different from distilled water, the free ammonia was reduced from 0·032 grain per gallon to 0·001, and the albuminoid ammonia from 0·013 grain to 0·0045. The "revolver" turns at the rate of about ¼ revolution per minute, and requires scarcely appreciable power. The area occupied by apparatus for dealing with 2,000,000 gallons per day is 29 ft. by 24 ft., and it can be introduced into any existing system of filters, for by enlarging the inlet and outlet pipes to a suitable diameter, a head of some 12 in. will suffice to pass the water through. It can easily be arranged so as to be used or not, as the state of the water to be purified may warrant, and the consumption of iron, being only about 20 lb. per million gallons, is quite an insignificant expense. It will be found to remove all color from water, whether caused by peat or clay, and will facilitate the action of sand filters by the peculiar curdling effect the iron has on the impurities. During the experiments made at Erith, it was noticed that considerable quantities of gas collected in the upper part of the "revolver."

On collecting this gas, it was found to extinguish a lighted taper instantly, and on analysis was found to contain only 8 per cent. of oxygen. It was observed from the first that the animal and vegetable life which was so abundant and troublesome in the natural waters of the Nethe, lying over the spongy iron filters, had quite disappeared in the water, otherwise in exactly the same circumstances, lying over the sand filters, and I always supposed that this was due chiefly to mechanical filtration through the spongy iron having separated all the germs, spores, and seeds which come to life above it. But during the recent hot weather it has been found that the water from the "revolver," though it contains all the impurities of the natural water, has been modified by the action of iron to such an extent that neither animal nor vegetable life is apparent over the sand filters. Without presuming to draw very wide inferences from this fact with reference to the action of iron upon organisms connected with disease, it may, at least, be pointed out that the absence of visible life in water treated by iron on a large scale confirms, in a great measure, the experiments of Dr. Frankland, Dr. Voelcker, Mr. Hatton, Professor Bischof, and others.

It is due to the last named gentleman to state that to his persistent advocacy the introduction of iron as a purifier is mainly due. It must be borne in mind that the system does not depend on filtration only, but, first, on a process of exposure to iron, which decomposes the organic matter, and kills living organisms; and, secondly, on simple filtration, which merely separates the noxious matters which had been previously attacked by the iron. The waters of the Nethe are exceptionally bad, and heavily charged with impurities, so that the test both of Professor Bischof's and Sir Frederick Abel's systems has been very severe.

THE PREPARATION OF HYPOSULPHUROUS ACID, AND ITS USE IN THE DEVELOPER FOR DRY PLATES.

THE advantage of the use of sulphite of soda and sulphurous acid in developers for dry plates in preventing discoloration and the staining of the negative has become well recognized among photographers. The chief function of the acid and sulphite appears to be the absorption of a certain amount of oxygen, thereby preventing the oxidation of the pyrogallic acid. Hyposulphurous acid absorbs a larger quantity of oxygen than sulphurous acid, and is hence of greater utility.

Referring to this matter, the *Br. Journ. of Photo.* describes the preparation of the acid as being extremely easy, and says:

"Hydrosulphurous or hyposulphurous acid—H_2SO_2—is formed by the action of zinc upon the aqueous solution of sulphurous acid; the latter dissolves the metal without, as in the case of most acids, the evolution of hydrogen, the reaction being represented by the equation

$$Zn + H_2SO_3 = Zn\,O + H_2SO_2.$$

Hyposulphurous acid, it will be seen, contains one atom less of oxygen than does sulphurous acid, and possesses far more powerful reducing and bleaching power. It is, however, extremely unstable, and therefore practically inapplicable to our purpose. A more stable compound is found, however, in the sodium salt of the acid, as recommended by M. Sammann; this is easily prepared by submitting the acid sodium sulphite (or bisulphite) to the action of metallic zinc in a stoppered bottle. The zinc is dissolved, as in the case of the free acid, without evolution of hydrogen, a solution being formed, which contains zinc-sodium sulphite, together with sodium hyposulphite. The latter may be isolated by the adoption of special means; but for our purpose this is quite unnecessary, more particularly as the instability of the salt, when so purified, scarcely justifies the trouble. For the purposes of development, or of preserving the pyro solution, the compound solution answers all requirements, and its preparation involves no further care than the pouring of a saturated solution of the acid sodium sulphite into a bottle partly filled with granulated zinc, or clippings of the metal.

A ten ounce wide-mouthed bottle is filled about three parts full of clippings or granules of metallic zinc, which should first be cleaned with dilute sulphuric acid, followed by copious washing in pure water. Into this receptacle is then poured the saturated solution of bisulphite of soda, which in about half an hour's time will be converted into the solution named above. It is then poured off, filtered from the white basic zinc salt which is formed, and preserved in a closely stoppered bottle; but it rapidly oxidizes, and is reconverted into acid sodium sulphite.

This solution, from its greater reducing power, or its stronger affinity for oxygen, should be, and in fact is, a far better preservative of pyro than either sulphite of soda or sulphurous acid; indeed, the first change that occurs is its oxidation to sulphite, or in other words, its conversion, after having performed a fair share of work, into the material with which we are at present in the habit of commencing operations. Despite its instability, when kept by itself, it is quite probable that in contact with pyrogallol it will acquire a higher degree of permanence, since both it and the pyro will be, as it were, pulling in contrary directions in their struggles to absorb oxygen. At any rate, it must be a more efficient agent than the sulphite, since it insures the presence in solution of a large proportion of oxygen absorbing material, with a minimum of material already oxidized into sulphate, a condition of things too often prevailing when many samples of so-called sulphite of soda are used.

THE AMERICAN OIL AND GAS FIELDS.*

By Prof. JAMES DEWAR, F.R.S.

WHEN the secretary of the Society and I were in America—I left him at Washington to proceed to the oil district, he being engaged on other duties in connection with the present exhibition—he suggested that I might give some account of the district, and I certainly entertained that view; but, unfortunately, much abler men, who are infinitely better qualified than I am to discuss this subject, have, in the mean time, treated of it before the scientific world. I refer especially to the paper by our honored Chairman, Sir Frederick Abel, and to that which has been delivered before the Chemical Society by Mr. Boverton Redwood. I was therefore forced to the conclusion that I had better deal with generalities; that is to say, instead of confining myself to details of what I saw in America, I would give a general account of the petroleum industry. I have been very much aided by the recent publication of the most exhaustive monograph which has ever appeared on the subject of petroleum. This monograph has been prepared for the American Government by Mr. Peckham, and is a huge volume which represents nearly one-half of the reports of the tenth census of the United States. A careful study of this monograph will enable the student to reach very definite conclusions upon the subject, because it is there treated in the most elaborate manner. In the first place, the facts in regard to the historical development of petroleum may be summed up as follows: In past ages petroleum has been gathered from natural springs and has been used as a medicine, and in a rude way as an illuminating agent.

Long ago, it was obtained by artesian borings in China. The development of the coal oil industry, between 1850 and 1860, led to experiments upon petroleum as a substitute for the crude oil obtained from coal, and in 1859 there came a demand which led to Drake's attempt to obtain petroleum by boring. The success attending the oil industry in Pennsylvania during the first four years of its existence led to the organization of companies all over the world for the purpose of drilling test wells wherever springs of petroleum were accessible. In some localities they were successful, in others only partially so, while in the majority of instances they were failures, or were found inferior to the primitive dug wells. The continuously increasing and enormous production of the United States, and the consequent depreciation in value of all the products manufactured from petroleum, has led to the almost complete control of that trade by American manufacturers, Galicia and the Caucasus at the present time being their only competitors, and they only to quite a limited extent.

An examination of a map will show that bitumen occurs on the American continent along a line extending from Point Gaspe, in Canada, to Nashville, Tennessee, and in Europe and Asia along a line extending from Hanover, on the North Sea, through Galicia, the Caucasus, and the Punjab. These are the principal lines. In America, it also occurs on the Pacific Coast from the bay of San Francisco to San Diego; again, from Northern Nebraska to the mouth of the Sabine River, on the Gulf of Mexico; again, from Havana near the western end of Cuba through San Domingo and the circle of the Leeward and Windward Islands to Trinidad, thence westward on the mainland to the Magdalena River, and southward from that point to Cape Blanco, in Peru. In Europe and Asia bitumen occurs on the lower Rhine, and in the valley of the Rhone; from Northern Italy, following the Apennines to Southern Sicily; along the eastern shores of the Adriatic, through Albania and into Epirus; again, along the depression in which lies the Jordan and the Dead Sea; again, along the mountains that border the valley of the Tigris in the east; again, from Western China through Burmah, Pegu, Assam, Sumatra, and Java; and lastly in Japan. It will be observed that these lines are, for the most part, intimately connected with the principal mountain chains of the world.

Petroleum occurs in crevices only to a limited and unimportant extent. It occurs saturating porous strata, and overlying superficial gravels; it occurs beneath the crowns of anticlinals in Canada and West Virginia, but does not so occur in Pennsylvania. In the latter region it occurs, saturating the porous portions of formations that lie far beneath the influence of the superficial erosion, like sand bars in a flowing stream or detritus on a beach. These formations or deposits, taken as whole members of the geological series, lie conformably with the inclosing rocks, and slope gently toward the southwest. The Bradford field, in particular, resembles a sheet of coarse grained sandstone, 100 square miles in extent, by from 20 ft. to 80 ft. deep, lying with its southwestern edge deepest and submerged in salt water, and its northeastern edge highest and filled with gas under an extremely high pressure.

It is further to be concluded that, from whatever source the petroleum may have originally issued, it now saturates porous strata, not of any particular geological age, but runs through a vast accumulation of sediments from the oldest to the newest rocks, in Pennsylvania and West Virginia, embracing all of the rocks between the Lower Devonian and the Upper Carboniferous.

The experience gained in drilling wells also shows the presence of fissures below the surface. Wells are sometimes started, and after passing through several strata reach one where, in spite of all attempts to remedy the evil, the hole will go crooked, the drill glancing from the rock on the one side of the fissure, and the well, in consequence, has to be abandoned. At the same time, the extent to which fissures exist in the deep beds of oil sands is now believed to have been very much overrated. The experience gained in sinking deep wells leads rather to the conclusion that in them the drill penetrates a homogeneous solid sandstone, in the pores of which the oil is held under great pressure.

The motion of oil laterally through the oil sands is illustrated by numerous phenomena attending the drilling operation of contiguous wells. It is observed that the wells and springs of water in the superficial strata fail when these strata are penetrated by deep wells. Even artesian wells sunk for water to the second sand are often drained by contiguous oil wells sunk to the third sand, in consequence of the lateral movement of the water through the second sand to the oil well. The capacity of a porous sandstone, or even the coarse pebble conglomerate constituting the Venango third sand, to hold the vast quantity of oil that has poured fourth from some wells has been questioned; but when we consider, 1, the strong attraction of existing oils and dry surfaces, 2, the powerful capillary attraction exerted in consequence, and, 3, the enormous pressure under which the oil is held in the rock, and forced out when the reservoir is perforated, there seems to be no reasonable ground for doubting the sufficiency of such a source of supply.

Mr. J. F. Carll has shown by experiments that the pebble sand will absorb from one-fifteenth to one-tenth of its bulk of oil, and further that "the aggregate sum of the pores or interspaces of a sand rock of this kind, as exposed in the walls of a well of 5½ inches in diameter, is equivalent to the area of an open crevice one inch wide, extending from top to bottom of the gravel bed, whatever its thickness may be." He further shows that "On an oil creek there is generally from 30 feet to 50 feet of third sand, and also from 15 feet to 30 feet of stray sand, both locally producing oil. Of this total, suppose only 15 feet is good oil-bearing pebble; we shall then have a producing capacity of 15,000 barrels per acre, or 9,600,000 barrels per square mile, which is adequate to the requirements of the most exceptional cases known."

Dr. Hunt estimates that a layer of Niagara limestone of Chicago (an oleiferous dolomite) 1 mile square and 1 foot thick will contain 1,184,832 cubic feet of petroleum, equal to 8,850,069 gallons of 231 cubic inches, and to 221,247 barrels of 40 gallons each. Taking the minimum thickness of 35 feet assigned by Mr. Worthen to the oil-bearing rock at Chicago, we have, in each square mile of it, 7,743,745 barrels, or, in round numbers, 7,750,000 barrels of petroleum.

The question as to the origin of petroleum is one as to which three suggestions have been made: First, that it is due to the continued operation of chemical processes at great depths; secondly, that it is really indigenous to the rocks in which it is found; and thirdly, that it is due to the natural process of distillation. Now, the supporters of either of those views have always some particular data which are certainly favorable to that particular way of regarding it. In the first place, the enormous quantities of oil which have been produced from certain localities seem either to show that the supply is connected with enormous underground chambers, or else that there seems to be some means of continuous renewal. The chemical theory, therefore, is able to account for the continual formation of petroleum. On the other hand, either if it is indigenous or produced by the natural process of distillation, it is connected with geological changes which we have no reason to believe are operating at the present moment.

Consequently, the theory we adopt bears on the permanence of the supply of petroleum. Now, before giving you one or two illustrations, I may just mention that there are all possible varieties of this fluid, varying in character, in density, in boiling point, in solvent properties, and in all the general modes of characterizing these activities. Here you have a series which represents a very complete series of the Russian petroleum; crude, purified, with all grades of intermediate boiling points. In front, I have a fine series of natural petroleums, presented by Mr. Boverton Redwood. Now, it is undoubted that the petroleum of different districts does not agree in its uniformity. The petroleum of Canada contains sulphur, nitrogen, and is essentially different from that which occurs in Pennsylvania. In the same way the petroleum of California differs from either. Therefore, the chemical theory would require to be able to produce a very different kind of product at different places, and that of course is conceivable. Still, one would anticipate that if it was some kind of chemical action, we would have greater uniformity in the products than we have. The character of all these bodies is, that in the particular class of the American petroleum, they all belong to that series which we know very well as the paraffin series, and of which solid paraffin is the characteristic. The solid paraffin was discovered by Reichenbach, about 1826, I think, and was first analyzed by Gay-Lussac, in 1826. All these hydrocarbons contain the maximum

* A paper recently read before the Society of Arts, London.

quantity of hydrogen that the carbon can combine with, whereas the petroleum which characterizes the Russian field certainly seems to belong to a totally different series. The Baku oil contains members of the benzol series—bodies which we know seem rather to represent derivatives connected with high temperature changes, whereas the American petroleum resembles in its general characters that produced by distillation by Mr. Young's process at a low temperature.

That petroleum is in some way connected with the vastly abundant accumulation of paleozoic sea weeds, the trunks of which are so infinitely numerous in the rocks, and with the infinitude of coralloid sea animals, the skeletons of which make up a large part of the limestone formations, which lie several thousand feet below the Venango oil sand group, scarcely admits of dispute, but the exact process of manufacture, of its transfer, and of its storage in gravel beds is utterly unknown.

We may alter the composition of these oils by subjecting them to a high temperature. High temperature decomposes the more complex members of this series into gaseous and liquid members of lower boiling point.

In this way we can produce the more volatile from the less volatile, and this can be applied to the production of oils of what we may call low boiling point from oils of high boiling point. Mr. Young patented this process, but the Americans discovered a somewhat similar process long before—which they call "cracking." The vapor of the condensed petroleum falls back, and comes in contact with petroleum which is at a much higher temperature; they thus get superheated, and are partially changed into more volatile products. This "cracked" oil differs from the original in this respect, that it contains a larger proportion of members of the ethylene series. It is the decomposition of the more complex into the less complex. It has been suggested that it is possible that the less complex may be forced into the more complex, and that the recent enormous production of these gaseous oils may, in themselves, account for the production of the fluid, rather than the fluid or solid portions accounting for the production of the gas. The difference is simply that the denser hydrocarbons are produced from the more complex portions, and the bodies which result from high temperature are bodies which belong to a different series, and not to the same we meet with here. In the same way, the chemical theory which has been suggested by the Russian chemist Mendeleef is, that the carbides of the metals may exist at great depths in the earth, and that by the action of steam these are decomposed into the oxide of the metal, and hydrogen combining with the carbon, that produces the gaseous fluid—hydrocarbons. Now we know really that this action does take place. If we take a piece of ferromanganese which contains carbon manganese and iron, or say cast iron which is well saturated with carbon, and treat it with an acid, then the hydrogen is found to be mixed with hydrocarbon. Therefore, the carbides of the metals may react with the vapor of water, and produce hydrocarbons. It is quite true that the suggestion that the carbides of the metals may exist in large quantity is favored by the fact that we know that the density of the interior of the earth must be considerably greater than the mean density, because the density goes on increasing, and probably it may reach a quantity which is represented by something like twelve times that of water. The probable existence of iron manganese and other metals at low depths is consequently impugned. The view that petroleum is a product of distillation, probably at a low temperature, which has been caused by metamorphic action, seems to fit in best with all the facts we know regarding the distribution of petroleum.

It should be borne in mind that while this subject is one of speculation pure and simple, it is one that has its valuable consideration outside the domain of scientific inquiry or curiosity, as affecting the sources and duration of supplies of petroleum, its profitable development, and commercial permanence. If petroleum is the product of a purely chemical process, we should not expect to find paleozoic petroleum, of a character corresponding with the simple animal and vegetable organisms that flourished at that period, and tertiary petroleum, containing nitrogen, unstable, and corresponding with the decomposition products of more highly organized beings; but we should expect to find a general uniformity in the character of the substance, wherever found, all over the earth.

The advocates of the chemical theory affirm that they provide for a process the conditions of which are perpetually renewed. It is thus continuous, and at present active. On the contrary, if petroleum is the product of metamorphism, its generation is coexistent only with that of metamorphic action, an action which we have no reason to believe has been prevalent on a large scale during any recent period. If we accept this hypothesis, the generation of petroleum is then practically ended.

Some of the most remarkable advances which one cannot help noticing in America is the rapidity with which oil wells are sunk, 1,500 or 2,000 feet being pierced in the space of something like a month or two at the most, and the facility and regularity with which this operation is continuously carried on without any of the dangerous accidents which formerly occurred in connection with this enterprise. The drilling, in itself, would really supply matter for an exceedingly interesting paper.

The early method of drilling, with the well full of water, prevented the escape of the oil and gas until the water was pumped out. When the rock is pierced with a hole drilled dry, the effect is similar to the sudden liberation of the safety-valve of a boiler under a full head of steam; the boiling, foaming mass is driven upwards against the forces of gravity, and sometimes shoots high above the top of the derrick. The equilibrium which has been maintained for ages throughout the communicating portions of the rock is suddenly destroyed, and material, gaseous at the ordinary temperature and pressure, but fluid under the enormous pressure maintained in the oil rock, expands and evaporates as it rushes to the surface. This action goes forward, slowly reducing the pressure upon all the communicating portions of rock, until the pressure on the oil filling the rock is only equal to that of the column filling the drill-hole. Considering, then, that the oil is often forced up to the surface from a depth of 1,500 or 2,000 feet, we can calculate from the density of the oil the maximum pressure, which may often range from 30 to 50 atmospheres.

The pump is now used to lift the fluid from the drill-hole, the oil being still under the pressure of the gas, ascending between the tubing and the casing. The rock is still full of oil, and the pumping goes on, until the pressure of the gas is scarcely sufficient to send any of it to the surface, when a gas-pump is applied at the casing head to one of the lateral tubes, and the pressure of the atmosphere removed. Still, after all this, there is oil remaining in the rock. As before intimated, the oil and gas mutually dissolve each other and form a homogeneous mass, "the gas being as thoroughly incorporated with the oil as gas is with water in a bottle of soda-water."

This probably explains the enormous proportion of gas along with petroleum. The gas, under this enormous pressure, is exceedingly soluble in these oils of high boiling point. The result is that as the pressure is gradually relieved, the gas may be said to distill off from a strong saturated solution, and consequently the volume of fluid in the porous rock, which we were discussing in the case of the fluid petroleum, is not applicable to the volume of gas. We get gas, and although the gas may not be liquefiable, yet we may say it is approximately liquefiable in the particular solvent which dissolves it.

After the oil has stopped flowing, if the well owner does not pump, his neighbors' wells will drain his territory; and if he "pulls out," the law compels him to fill his well with sand, and ruin it forever, to prevent the public injury resulting from letting down surface water into the oil sand. There is, therefore, no other alternative presented to the unfortunate possessor of oil territory but drill and produce, whatever the price of oil may be.

Experience has proved that one well to five acres is as close as they should be drilled. The man who owns a lot has no safety but in getting his oil to the surface, otherwise he is constantly exposed to the risk of having it sucked dry by the well of his more energetic neighbor.

We, as a nation, are very much in the position of the owner of oil territory in regard to our coal supply. In discussing the question of an export duty on coal, Mr. Jevons came to the conclusion that "we must either retract the profession we have made to the world, and the principle we have so recently adopted, or else we must submit to see our material resources exhausted in a shorter period than could have been thought possible." This curve on the diagram on the wall represents the growth of coal consumption in this country from 1854 to 1884. You observe that it is a wonderfully symmetrical curve, and that it has a periodic regularity. For about four years after 1854 there was a very slight increase, then a rapid growth, and again a slight diminution. The minimum periods are about every ten years. The mean position of this curve supports the view originally taken by Sir William Armstrong, that an arithmetical progression was most probably the law regulating our coal output. We see that in the near future the quantity of fuel will be small, and, therefore, we are very much in the position of the oil proprietors; we must exhaust our treasures, or else we shall be behind in the race.

The distribution of petroleum from the oil districts, and the mode of conveyance, is certainly one of the most striking developments of the industry, and a visit would not be complete without viewing a reach of the enormous pipe-lines and pumping-stations which convey the oil from something like 21,000 isolated oil mills of Northern Pennsylvania and carry it to Philadelphia, New York, Baltimore, etc. It is pumped from valleys over the hills, the highest elevation being in any one place above 1,500 ft. There are very varied and complicated problems connected with this mode of distribution—not only of pressure, but friction in the pipes. The pumping stations are distant from twenty to twenty-five miles, and the oil is pumped in from the twenty-mile station in advance into enormous reservoirs of 100 ft. in diameter; and 40 ft. to 50 ft. in height; it is again pumped out for another twenty-five miles, and so on to Baltimore and Philadelphia. It is remarkable that, although complaints have been made in the past of the waste of oil, comparatively little is allowed to waste. I was surprised that of the enormous outflow of oil which took place when the Philips well was started in September, so little was lost; it was pumped away in a narrow pipe laid at once to the nearest pipeline, so that even when an enormous rush of this kind occurs, there is very little waste of oil.

The problems in hydraulics presented in the construction and management of pipe-lines are many and intricate, and required great courage on the part of those who projected the first line to meet and surmount them. These men had only the quite different problems and experiences met in laying pipes for water to guide them. The pipe-line problems dealt with a fluid varying in density with the temperature, flowing easily in summer and with difficulty in winter through pipes of small diameter, laid hurriedly and frequently changed, often on sharp curves or at right angles, for rapid movement and delivery, and at high pressures, to compensate in part for the friction due to long distances and rapid transmission.

The trunk lines transport the oil of large areas to the cities of Pittsburg, Cleveland, Buffalo, and New York, under a high pressure, delivering thousands of barrels daily. They are laid for miles through the forest-covered hills and valleys of northern Pennsylvania and southern New York, across hills and rivers, on the surface of the ground, or only slightly covered. These main lines are 6-in. pipe, tested to a pressure of 2,000 lb. to the square inch, and joined with couplings, into which the lengths of pipe are screwed, as are ordinary gas or water pipes.

Only those firms and corporations under strict business habits really know approximately how many miles of pipes they own, and therefore an accurate enumeration is found to be impossible; but it is safe to say that there are thousands of miles of 2 in. pipe laid for transporting oil owned by the pipe-line companies.

The pumping stations consist of permanent buildings, a boiler house, and a pump house containing a steam and oil pump combined in one. Many of these pumps are of the Worthington pattern, and are very powerful machines, forcing the oil through great distances, not only over the hills, but against the friction of the pipe conveying the oil—an element of vast importance, as the friction increases enormously as the flow of oil is increased in rapidity. The friction on the 108 miles of 6 in. pipe between Rixford and Williamsport, Penn., is found to be equal to a column of oil 700 ft. in height, *e. g.*, if the pipe were laid on a uniform descending grade of 700 ft. between the two points, and filled with oil, the friction or the adhesion between the oil and iron would prevent the oil from flowing. For these reasons, the pressure carried on these pumps is frequently from 1,200 lb. to 1,500 lb. to the square inch.

Along with this admirable mode of distributing the petroleum, and the elegance and accuracy of the workmanship in laying the mains, there are a great many problems which suggest themselves. In the first place, the troubles which are caused sometimes by the plugging of the wells with solid paraffine. This is probably due to the fact that under the high pressure in which the lighter portions of the naphtha dissolved in the heavier ones exist, the paraffine is more soluble, and consequently, when the expansion of the gas takes place, and the temperature is lowered, the paraffine crystallizes and coats the pipe to the extent of often 100 ft. This explains the stoppage of the supply of gas from the gas wells. They are not actually exhausted of gas, but they are simply, for the time being, plugged either with brine, solid salts (such as chloride of calcium, or paraffine. The paraffine is removed by taking out the pipe and melting it. When wells cease to flow, they sometimes apply an exceedingly interesting device, viz., torpedoing, that is to say, they sink something like sixty to eighty quarts of nitro-glycerine, which is an enormous quantity, and would correspond to a very much larger proportion of dynamite, and fire it at the bottom of the well, the effect being to induce a flow of oil for the time. This plan was introduced, I think, in 1865, was found to be satisfactory in some cases, and has been continued. The most interesting point is that when this is fired there is no sound, and no rush of gas from the 2,000 ft. bore. There is no apparent production at all of an explosive effect. This evidently loosens the pores, the enormous gas pressure acting locally, probably from the incrustation of solid hydrocarbons; and when this is relieved, it clears the strata and allows the oil again to flow.

Before I go on to speak of one or two other points connected with the distribution and origin of the industry, I should like to see if we could manage to show you the character of one or two of the liquid hydrocarbons, which are usually gaseous. For this purpose we have compressed two of these hydrocarbons, which are the most typical. These two large iron bottles contain, the one, compressed ethylene, and the other compressed marsh gas.

The marsh gas is the simplest member of this paraffine series. It is a gas which we might say is permanent, that is to say, no amount of pressure will liquefy it under ordinary conditions. What I want to prove is this, that the enormous production of marsh gas which takes place in all these natural gas wells cannot be accounted for by any supply of the liquid gas. In order to liquefy a gas, we not only require pressure, but we must be able to work below a certain limited temperature for each gas. That limited temperature is called the "critical point." It so happens, the critical point of marsh gas is exactly 100° on the other side of the freezing point. In fact, we require to work below or just above 100° below the freezing point of water at a high pressure, in order to liquefy the gas. Considering that these gases, which are the chief constituents of natural gas, come in such enormous quantities from depths of 1,500 to 2,000 feet, where the temperature has gradually gone on increasing with the depth, there is no possibility of explaining the supply by any possible liquefaction, because the temperature reached is far above the critical point of either gas. I hope to be able to show you liquid marsh gas, though there is of course some difficulty in doing it in this room. In order to do this we require to liquefy two other gases; first, carbonic acid, which we inject into air, producing a large quantity of solid, which solid we use for the purpose of collecting a quantity of liquid ethylene. This liquid ethylene boils at a temperature of minus 100°. Into that fluid which will boil at 100° below the freezing point of water we will place a glass tube, into which we are going to compress marsh gas to the extent of 50 or 60 atmospheres, and if we are successful, we may be able to see that it begins to liquefy, and even possibly I may be able to show you the marsh gas in a solid condition. It becomes solid at a temperature of nearly 200° below the freezing point. There you observe the fluid, and on expansion the solid will form. This is the first occasion on which marsh gas, in the liquid and solid form, has been exhibited to an audience.

Here are some of the analyses of the gas, which have been made by the assistant at Mr. Carnegie's works, near Pittsburg. As I have stated, both Sir Frederick Abel, and Mr. Boverton Redwood have exhausted, recently, the petroleum question, and Mr. Carnegie has exhausted the oil wells by an interesting paper, which was communicated last week to the Iron and Steel Institute. However, he was kind enough to send me these analyses before he published them, and I have had this table made from them. The wells all occur within a radius of about sixteen miles of Pittsburg, and there is evidently a clearly defined gas belt, which lies, apparently, at the summit of the anticlinal reach, which supplies petroleum, and there seems to be inexhaustible supplies of gas.

No. 1.

When tested	Oct. 28, 1884.
Carbonic acid	0·8 per cent.
Carbonic oxide	1·0 "
Oxygen	1·1 "
Olefiant gas	0·7 "
Ethylic hydride	3·6 "
Marsh gas	72·18 "
Hydrogen	20·02 "
Nitrogen	Nil.
Heat units	728,746

No. 2.

When tested	Oct. 29, 1884.
Carbonic acid	0·6 per cent.
Carbonic oxide	0·8 "
Oxygen	0·8 "
Olefiant gas	0·8 "
Ethylic hydride	5·5 "
Marsh gas	65·22 "
Hydrogen	26·16 "
Nitrogen	Nil.
Heat units	698,853.

No. 3.	
When tested	Nov. 24, 1884.
Carbonic acid	Nil.
Carbonic oxide	0·58 per cent.
Oxygen	0·78 "
Olefiant gas	0·98 "
Ethylic hydride	7·92 "
Marsh gas	60·70 "
Hydrogen	29·03 "
Nitrogen	Nil.
Heat units	627,170

No. 4.	
When tested	Dec. 4, 1884.
Carbonic acid	0·4 per cent.
Carbonic oxide	0·4 "
Oxygen	0·8 "
Olefiant gas	0·6 "
Ethylic hydride	12·30 "
Marsh gas	49·58 "
Hydrogen	35·92 "
Nitrogen	Nl.
Heat units	745,813.

No. 5.	
When tested	Oct. 18, 1884.
Carbonic acid	Nil.
Carbonic oxide	1·0 per cent.
Oxygen	2·10 "
Olefiant gas	0·80 "
Ethylic hydride	5·20 "
Marsh gas	57·85 "
Hydrogen	9·64 "
Nitrogen	23·41 "
Heat units	592,380.

No. 6.	
When tested	Oct. 25, 1884.
Carbonic acid	0·30 per cent.
Carbonic oxide	0·60 "
Oxygen	1·20 "
Olefiant gas	0·6 "
Ethylic hydride	4·8 "
Marsh gas	75·16 "
Hydrogen	14·45 "
Nitrogen	2·89 "
Heat units	745,591.

This diagram represents the volume of air required for combustion and the quantity of heat units produced by the various samples. There were something like five different pipe lines supplying gas to Pittsburg when I was there. The most interesting fact is that the enormous steel works of Mr. Carnegie are supplied with this gas, and you can see forty or fifty furnaces without any stoker, without any appearance of smoke, with no one evidently in attendance, and everything working automatically. You look at the pressure gauge, and you see it is recording a pressure of something like 75 lb. to the square inch. Of course, the pressure at the well was greater; they cannot use all the gas, and it is passed on to the next works. The use of this gas, to a limited extent, has been known since 1840, and certain places have used it for lighting. Accidents occurred, and undoubtedly it is dangerous, from the fact that it has very little smell. It differs from our coal gas in that respect, and in this way, unless the pressure is equalized, it is liable to escape, and so form an explosive mixture. There are certain differences, which you see pointed out, in the diagram on the wall, between the coal gas and the natural gas.

Coal gas explodes with about six volumes of air to one of gas, whereas six volumes of air does not at all produce an explosive mixture with this natural gas; it requires ten volumes of air to explode natural gas, whereas six volumes is enough for coal gas. This gas is produced seemingly in inconceivable quantities. It has in many cases gone on blowing off from old wells for a period of ten, twelve, and even twenty years. Some have actually produced thirty million cubic feet per diem. When we begin to talk of millions of anything, it is inconceivable to the human mind, so that I will put it in this way, in order to show you the magnitude: Let us consider the enormous quantity of coal gas wanted in London for our daily supply. If we had two of these gas wells, yielding 30,000,000 cubic feet, that would be sufficient to supply the whole of London with gas; and from nine to ten wells would be sufficient to supply the whole consumption of gas in Great Britain. Therefore, with this enormous storage of fuel around Pittsburg, which is so lavishly supplied with coal (because the darkness of Sheffield is really bright sunshine to Pittsburg, from the coking operations), it is not at all unlikely that, within a very few years, this coal charged atmosphere will be materially improved. All the more important works in Pittsburg are now able to use this natural gas. I visited the well sunk by Mr. Westinghouse (the inventor of the railway brake), in his back garden, near Pittsburg.

I heard a howling sound going on, which proceeded from the well. On applying a lighted sponge to the top of the projecting iron pipe, a huge flame of sixty feet in height shot up. The gas goes on blowing off at an extraordinary rate, yet a remarkably constant pressure is maintained, and I need not say that this enormous expansion is attended with considerable reduction of temperature, so that near the top there is an ice coating on the whole of the pipe. During the production of gas one might use it as an admirable freezing machine, apart from its great power as an antiseptic agent. This diagram on the wall gives you some idea of the heat units yielded by one cubic foot of gas, and the cubic feet required to evaporate one pint of water. The cubic feet of hydrogen required is nearly 3, and water gas 3½, blast furnace gas 10·38, carbonic oxide 3·13, and marsh gas 0·938.

The next diagram represents the production of petroleum in America, which evidently reached a climax for the time being in 1882, when it reached the enormous quantity of 31,000,000 barrels. The only other field which bears any comparison with this field is undoubtedly the remarkable field described by Mr. Redwood. The output of Russian petroleum has reached one-third that of the United States. The character of the oil is different; it does not contain anything like the quantity of what you may call burning oil, but yields a very high class lubricating oil, and the higher boiling point oils, although they do not contain solid paraffin, contain vaseline, and are exceedingly useful as liquid fuel. The only field which may be regarded as a competitor to America is undoubtedly the Russian oil field. These two curves represent the growth of American petroleum and the Russian oil industry.

Here is another diagram, on which you see the quantity of exports and the quantity of petroleum used in different countries: German ports, 100 million gallons; England 70 million gallons; Belgium, 43 million gallons; France, 39 million gallons; East Indies, 31 million gallons; Holland, 21 million gallons; Italy, 18 million gallons; Austria, 18 million gallons; India, 17 million gallons; Spain, 13 million gallons.

The daily demand for petroleum is something like 40,000 barrels. At present the Americans have stocked something like forty million barrels, which is equivalent to something like a three years' supply, that is to say, suppose the American oil-fields stopped tomorrow, there would still be from two to three years' supply stored in the numerous reservoirs of the United States pipe-lines. What I have already said explains why, even though there is such an enormous quantity of petroleum stored, the production of oil goes on incessantly, and that it is apparently not diminishing, but increasing. When I left America, the great sensation was the Philip well, and I was astonished to receive, upon landing, a letter from a friend, from which I extract the following sentence: "Since you sailed, there has been the Christy well, which yielded double the quantity of the Philip well, and now comes the Armstrong well, in the same district, that far surpasses either. Crude petroleum went down to 59 cents, and the whole stock in the United States declined in value more than two millons of dollars in two days."

It is interesting in connection with the genesis of petroleum just to refer to the explanation of the origin of it from woody fiber. It is also interesting to consider at what rate we are using our coal in comparison with the rapidity of vegetable growth over an equal area. Coal being produced by the transformation of cellulose, it is easy—from the quantity of wood which can be produced in a given area, or from a given surface of green leaf—to ascertain what this would be, and, shortly, it is this. When we compare the total energy which the sun gives on the area of the leaf in the quantity of store power which the leaf gives us in the form of cellulose or storage, we find we have only one out of 132; that is to say, we have it in the ratio of 1 to 132; there is 132 times the energy available, but we can only manage to secure one of them. That might be said to be an exaggerated estimate, because the efficiency is not due to the total energy, which is largely composed of heat, but is essentially due to the light portion.

Let us take the energy of the light portion alone. If the light portion of the spectrum is considered, the ratio is 1 to 43—that is to say, we only economize one forty-third part of natural sun-light. Now, this is not the efficiency of a good, or even of an old, bad working, steam-engine. One to 42 would be considered a serious loss of energy, apart from the enormous surplus which is evidently wasted in space, of which we cannot conceive any use in the mean time, unless other worlds can economize it. We see that in the efficiency of vegetation we have nothing like the efficiency we have in mechanical appliances such as the gas-engine.

The development of the oil territory proceeds, after its existence has been demonstrated, without regard to any other interest. The derrick comes like an army of occupation. The farms, fields, orchards, or gardens alike are lost to agriculture and given to oil, and on the forest-covered hills the most beautiful and valuable timber is ruthlessly cut and left to rot in huge heaps wherever a road or derrick demands room, while here and there the vast storage tanks stand, a perpetual menace to everything near that will burn. Nothing I ever beheld reminded me so forcibly of the dire destruction of war as the scenes I beheld in and around Bradford. But the wave of desolation passes over, and nature changes the scene in the same manner as she gathers and restores the ruins of battlefields. The famous Pithole City, which in 1865 was, next to Philadelphia, the largest post office in Pennsylvania, showed a farmer plowing out corn where the famous Shearman well had been; a waving field of timothy where the Homestead well had been; the site of the famous United States well hardly to be found by one who had known it all though its career; and of the city there remained but fifteen or twenty houses, rapidly tumbling to decay, but not an inhabitant. The country around this scene of so much activity, fifteen years ago is growing up to forest, and is not now valued at an amount equal to a year's interest on the valuation of that time. The Oil Creek region has now returned to the condition of an agricultural and manufacturing community. On the lower Allegheny, in Clarion and Butler counties, the production of oil has become much lessened in importance, and the wreck of abandoned derricks in many localities presents a dismal picture. The Bradford field is now in fully developed activity, and the destructive subordination of every other interest is everywhere painfully apparent. Yet the towns that are the result of the oil industry are scarcely more substantial than a military camp, and are infinitely less inviting in their appearance.

Looking toward the past, it may be said that petroleum has become the light of the world. It is fast displacing vegetable and animal oils as a lubricator on all classes of bearings, from railroad axles to mule spindles. It is also displacing animal and vegetable oils where such oils are liable to spontaneous combustion; it is becoming one of the most largely used materials for fuel in stoves, both for cooking and for heating purposes; it is very successfully used for steam purposes where other fuel is scarce and petroleum is plenty; it is found to be available in the metallurgy of iron, and is likely to be in demand for the production of pure iron for special purposes; its merits have been long recognized in medicine, and it is rapidly becoming a necessity in the form of petroleum ointment: in fact; petroleum has become one of the indispensable needs of civilized man, and ministers to his wants in such a multitude of forms, and under such a variety of circumstances, that it may be safely said that it ameliorates the conditions of his struggle with external nature, adds comfort to health, and soothes in sickness, prolonging his active life by extending the day into the domain of night, over all that portion of the earth's surface accessible to commerce.

It is to the Americans the merit belongs of having given to petroleum this last right of citizenship among the industries. The native talent that leads them to regard the useful aspect of everything; above all, the feverish but patient activity, seconded so well by a happy temperament, has served them marvelously on this occasion.

During the discussion which followed, Prof. Dewar said, with regard to the sufficiency of oil for naval purposes, the experiments of Dr. Nobel and of Sir Frederick Abel, at Woolwich, showed that coal, being equivalent to an evaporation of 7½ lb., of water, petroleum gave an evaporation of 13 lb. very nearly in the ratio of two to one; and Nr. Nobel had now, with a large surface of flame, obtained the result of 14½ lb. to 7 lb. The Americans only suggested the use of petroleum as an emergency fuel, in time of war; it was not intended to employ it continuously. The Russian petroleum residue was used continuously as fuel on all the Russian railways, extending now even to the frontier of Afghanistan. Its economy was enormous, requiring little superintendence or skilled labor. Another advantage was that it could be instantaneously put out. Americans suggested that ships should be built with large holds, as Mr. Nobel has constructed his steamers for the Caspian, for storing fuel, in addition to the coal supply, so that when steam had to be got up very rapidly, the petroleum could be used. He had not been able to procure details with regard to the French well mentioned. Similar attempts were being made in Italy at present, but they were in much the same position there also as had been described in the other case—they had obtained gas, but no oil.

The late Emperor had induced Professor Deville to examine the petroleum, and we certainly owe a great debt of gratitude to France in this matter. He had no hesitation in saying that the main credit for the first industrial adaptation of the schists for oil purposes, on a manufacturing scale, was due to France. With regard to the application of these gas wells, there were two places where a very fine lamp-black was made in that way, but he had unfortunately not been able to get access to the factories. The Standard Company had, however, given him every facility for seeing their works, and it was simply astounding to see a machine turning out 4,000 boxes a day with only two men standing by it; all the nails were put in automatically, and as fast as the wood was put in, the boxes completely made were thrown out. In another factory, which he had also been unsuccessful in getting into, very fine carbons for the electric light were similarly made.

SLATE ROOF COVERINGS.

WE clip the following from a lecture recently delivered by Mr. John Slater before the Carpenters' Company, London:

I now come to what is probably the most extensively used roof covering at the present day—slate. You know that tiles are formed of burned clay; but what is slate? Many of you will probably be somewhat astonished when I tell you that slate itself consists of very little else than clay. Ages and ages ago the action of water was depositing in various places layer upon layer of very fine clay or mud, mixed with a little sand, and these layers gradually accumulated to a considerable height; then vast geological changes took place, and this clay became buried deeper and deeper under superincumbent masses of material, and was subjected to enormous pressure and enormous heat, till it became completely consolidated. That is also the way in which most of our building stones have been formed, and the bed of the stone is determined by the direction of the original layers; but in the case of slate, enormous terrestrial forces have acted on it in a lateral direction, and they have been so intense as to rearrange the layers so that they frequently lie in quite a different direction from that in which they were originally deposited. Along the lines of the new layers slate can, as you all know, be split into very thin sheets, and this quality renders it a most useful building material, because, although it is very hard and dense, it can be obtained so thin without breaking that the weight of a superficial foot is very small, and, therefore, when used as a roof covering, it does not need a heavy supporting framework. Slate is one of the most compact and close-grained rocks, and has a smooth surface, so that water runs off it very easily, and consequently it can be safely laid on roofs at as low a pitch as 22½°. Curiously enough, it is most probable that its use was brought about by the necessity of finding some close-lying, easily cut material for covering the high-pitched conical roofs which the mediæval builders gave to their towers, as they were unable to cut tiles to suit these roofs. Notwithstanding this, its general introduction has acted prejudicially from a picturesque point of view. The quaint old lichen-covered tiled roofs upon which the eye rests with pleasure in many an old English country town have given place to the flat, dull, leaden-colored slated roofs, which frequently seem so ashamed of themselves that they are glad to retire behind a parapet. But this is an age of utility, and, though we may spare a word of regret for the picturesqueness of the past, there is no denying the fact that, from the point of view of closeness of fit, strength, and cleanliness, slates are superior to tiles for a dirty, smoky city.

CHARACTERISTICS OF GOOD SLATE.

The slates of North Wales are probably surpassed by none in the whole world, and I dare say many of you have visited the celebrated Penrhyn quarries, near Bangor, which are situated in the neighborhood of some of the finest scenery in the British Islands. There are, however, other very good qualities of slates to be obtained besides those of Bangor: Portmadoc slates, for instance, named from the port of shipment, but really obtained from Ffestiniog, Difwys, and other quarries in the neighborhood. In Cornwall the Delabole quarries are much esteemed, and in the lake district some excellent specimens of light green slates are found. Ballachulish and Dalbeattie, in Scotland, and Killaloe and Ashford Bridge, in Ireland, may be mentioned as the principal places in those countries producing good roofing slates. The characteristics of good slates are that they should be of a bluish-gray tint, uniform in color, and free from patches; that they should not be tender or friable at the edges; that they should have a good, clear, ringing sound when gently knocked together; and that they should absorb a very small quantity of water. If the color be too light, the slate will probably be of a stony, gritty texture; if it be a very dark blue, you will generally find it absorb water too readily. This quality of absorbing water is, of course, very important, and you can easily test it

for yourselves by placing a slate on end in a basin of water with about half its length immersed, and after remaining so for some time you will be able to see how far the dampness which is absorbed has risen in the dry part of the slate.

SIZES OF SLATE.

It will not be necessary for me to describe in detail the various sizes of slates used for roofing purposes, such as ladies, countesses, duchesses, etc., as you probably know the names and sizes as well as I do. The kind chiefly used in London are the countess slates, measuring 20x10 inches. It is necessary that slates should be laid so that each course overlaps to a certain extent the next but one below it, and the amount of this overhanging is called the lap. This should never be less than 2 inches, and 3 inches is better. There will thus be, as in tiles, a certain width of slate in each course exposed, and this exposed part is called the gauge, its width diminishing as the lap increases. The way to find what will be the gauge is to deduct the lap from the length of the slate and then halve the remainder; thus, if countess slates are to be laid with a 3 inch lap, the gauge will be $\frac{20-3}{2} = 8\frac{1}{2}$ inches. Each course of slates should, of course, "break joint" with the course below it, and a double course should always be laid at the eaves. The valleys in slated roofs are generally laid with lead, which should be turned up under the slates at least 9 inches on each side, and my own opinion is that lead is the best covering for the hip rafters, but sometimes thick saddle-back slates are used with an ornamental roll, similar to what is used for ridges. As nearly as possible 170 countess slates go to a square of 100 feet, and their weight is about 7 cwt.

LAYING SLATE.

Slates are laid either on battens, which are slips of wood, about 2½x1 inch, nailed on the backs of the rafters, or to close boarding, which is the best plan, and each slate should be nailed with two copper nails, but they should not be nailed down too tightly, or they will be liable to break during a heavy gale of wind. In France the slates are frequently not nailed at all, but secured by clips, the tops of which are secured to the battens, and the bottoms are bent so that the slates rest in them. The consequence is that the slates are free to move, and although they rattle terribly during a high wind, they are really less liable to be blown off. The reason why slates are broken and blown off a roof during a heavy gale is rather a curious one, and deserves a short consideration. At first sight it would seem that a throughly well-slated roof, with each slate carefully nailed, and fitting closely on the one under it, would really offer no purchase for the wind to get under the slates and rip them off. Nor does it, and yet the slates are ripped off, as we see, every time a gale of wind passes over a city. I believe the explanation to be this: Under ordinary circumstances, as you are aware, the pressure of the atmosphere is the same on all sides, and consequently when no wind is blowing the pressure on the inside of a roof is just the same as that outside. But during a heavy gale of wind there are always exceptionally strong gusts that occur at intervals; and when a particularly fierce gust of wind impinges on a roof, it is followed by a momentary vacuum. While this lasts, even though it be for two or three seconds only, the pressure on the inside of an ordinary roof is greater than the pressure on the outside, and the effect will be much as if a gust of wind were blowing from the inside. Now, whenever any pressure is brought to bear upon any material, it finds out the weak points. Just suppose that a gust of wind is blowing on the inside of a roof covered with slates on battens.

The slates cannot move where they are nailed; they will resist the pressure there, but at their ends they can easily be forced up; and if they are forced up at their ends while tightly nailed at top they must break, and I really believe that this vacuum which occurs is the cause of the ends of the slates being forced up and the slates broken off. This shows how much safer it is to close-board a roof than to use battens, and it also explains why slates hung on the French system are not so damaged during a gale. The ease with which slates can be cut to various patterns enables us, if we are disposed to do so, to give endless ornamental patterns to our slates, and in the middle ages builders were very fond of working their slates into all sorts of intricate forms, but you must bear in mind that slates when cut into patterns require more laps than when used square.

NEW MODE OF BUILDING SUSTAINING WALLS.

SUSTAINING walls may, as well known, be constructed in various ways. When the earth to be supported does not exert too great a stress, woodwork will answer, that is to say, a series of planks and vertical posts may be established along the bank, and other horizontal planks be placed between these pieces of wood and the surface of the slope so as to form a continuous casing. When it is judged necessary to have recourse to a masonry wall, the transverse profile of this may be given a trapezoid form, with the object in view of diminishing the cubage of the masonry. This wall then had a thickness that gradually increases from base to summit. At other times, for the sake of obtaining a saving, depressions are formed in the walls, and these are filled in with earth.

Theoretically, we may proceed still further in this direction, that is to say, it is possible to form the sustaining wall of earth merely, provided measures be taken to prevent the latter from caving in. This is the principle that has been applied in the breast wall that we shall here describe. Trestles or, better, species of trusses of appropriate material (preferably forged iron) are placed in a line as shown in the plan in Fig. 1. Between the uprights and the horizontal beams beneath, arched masonry is inserted with the convexity inward. This mode of construction is shown in Fig. 2.

By the use of this system we obtain a sustaining wall of earth that possesses as much stability as one of masonry.

In order to calculate the dimensions to be given to the uprights, it is well to consider them as beams rabbeted at the base. In the example cited by the author whom we are quoting, the wall is 16 feet in height above the level of the ground. It is supposed that it is sustaining a railroad embankment, and that the platform of the railroad is 3·28 feet above the level of the cap of the wall. Admitting that the weight of a cubic foot of earth is one hundred pounds, and the foundation invert is 3·28 feet below the level of the earth, calculation shows that the erection of the wall requires the use of 168 pounds of forged iron and 16

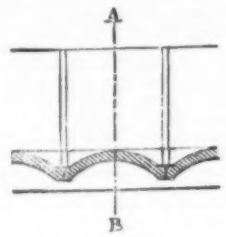


FIG. 1.—PLAN.

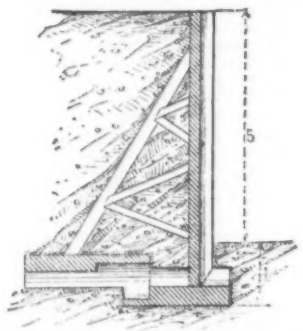


FIG. 2.—TRANSVERSE SECTION ON THE LINE A B.

cubic feet of masonry per running foot. From this may be easily deduced the cost price.—*Annales des Travaux Publics.*

THE HOOPING OF THE DOME OF ST. PETER'S, ROME.

IF guide-books and other descriptions of Rome are to be taken as evidence, it would seem that among the "things not generally known," the iron bands which encircle the drum and dome of St. Peter's may be included. Soon after Bernini had made staircases and niches in the great piers, it was observed that the cupola was rent, but no importance was attached to the defects. Carlo Fontana was appointed architect in charge of the Basilica, and he wrote a book to give the world assurance of the safety of the building. But in spite of talk and type, the cracks became larger, and in 1742 the subject excited commotion in Rome, when a scientific commission was appointed. The following account of their inquiry was compiled by Cardinal Wiseman from the original reports, and is published as a "Bygone" by the kind permission of Messrs. Hurst & Blackett. We may add that the conclusions of the reverend scientists were generally accepted. Out of nineteen opinions which were obtained on the report, the majority agreed that the hooping was the best device. Giovanni Poleni was, however, summoned from Naples, and he expressed an opinion that the dome was not in danger. He attached no importance to the cracks, which he considered were partly the results of the enlargement of some of the piers, by which they sank more than others, and partly the results of hasty building. The variation of the drum from the perpendicular he ascribed to settlements, and not to the pressure of the superincumbent dome. But as Poleni advised the adoption of five circles of iron around the dome, it may be said that he came to the same conclusion as the mathematicians, who proposed six colossal hoops to give security to the cupola. A sixth was added, and there are now eight. The work was completed in 1747, and was carried out under the direction of Luigi Vanvitelli or Van Witel, the architect of the Caserta Palace, the Convent of Sant' Agostino, and other buildings in Italy. Each hoop consists of thirty pieces, and they are covered with brick in order to be preserved from rust.

There is a popular idea current that Michel Angelo made the huge piers, on which the dome had to rest, so exactly proportioned to the weight they had to bear, that he even made a dying request that they should never be touched; that they were afterward perforated to make some staircases and niches, and that the consequence was, that the whole dome was threatened with ruin. All this is incorrect, as I will show you just now. It is not likely that Michel Angelo, whose characteristic was massiveness to excess, would have so offended. But in addition, it deserves to be mentioned that, at the time when he built these piers, a commission was appointed, of which I believe Raffaele was a member, to examine them; and that their report was, that the piers should be still further strengthened. Immensely deep wells were accordingly sunk at their feet, and filled with Roman concrete—which is the strongest, I suppose, in the world—so as to give great additional support.

It will be useful to give you the exact dimensions, in English feet, of the great masses concerned in what I am about to speak of.

Piers, on which the dome rests, 282 round.
Cupola, diameter, 141½.
Circumference, about 423.
Heights of arches on which it rests from the pavement, 146.
Height of lower edge of dome, 171½.
Total height to summit of lantern, 446¼.

Perhaps the greatest promise ever made by art, and faithfully kept, was here. Michel Angelo is said to have declared that he would raise the Pantheon up into the skies. These dimensions show how he kept his word.

About 1681, it was observed that there were numerous cracks in various directions, through the cupola; and great blame was thrown upon Bernini, who was accused of having made dangerous staircases and niches in the piers; however, his friend and biographer, Baldinucci, produced plans of earlier date, in which these alterations were marked; thus disproving that Bernini had been their author. He moreover speaks of the fissures then apparent as trifling. But they went on increasing. What are called in Italy seals—that is, marble dovetails—were placed across the cracks; and these broke, or were breaking with alarming rapidity. It was evident that the work of destruction was going on; and before the middle of the last century it was feared that, in a few years more, the whole dome of St. Peter's might fall in

Architects came forward to suggest various remedies for the threatened evil. One wanted to block up the windows, another to make great spurs or buttresses, in addition to the columns that surround the cupola, to give it strength. In truth, the whole structure would have been disfigured by the proposed expedients; but in reality, it was difficult to find a remedy. Benedict XIV., a most able and learned man, was Pope at the time. He wisely observed that this was not the business of art, but that it belonged to science. So he named a special commission of three mathematicians—pure mathematicians, having nothing to do with building or architecture—to examine the case. When I mention their names, scientific persons will easily understand how they were selected.

At the head of the commission was Father Boscovich, a Jesuit, who had twice measured arcs of the meridian, and had published a number of works on astronomy, on the spots on the sun, on optics, and many other philosophical subjects; a man, in truth, of European reputation, and one of the first men in Italy who accepted the Newtonian system. The other two were not Jesuits, but religious of another order. They were the editors of what is commonly called the Jesuits' edition of Newton, Le Sueur and Jacquiert; men purely and exclusively scientific. How did they go about their work? As scientific men would naturally do, with great care and caution, as well as ability.

As they drew up a minute report of their proceedings, under the modest title of "Opinion of Three Mathematicians," and presented it to the Pope, I have only to abridge their own account of them. It was given in at the close of 1742; and they commence their paper by apologizing for apparently intruding into a province not their own, and pleading for their excuse the sovereign command; showing, at the same time, how science has properly to deal with such a matter.

Their first care was to examine most minutely the entire dome, within and without, and form thus a plan of all the injuries which it had suffered. They give an accurate list of thirty-two distinct damages, some very severe, and running in various directions. The stone lintels over several of the windows were split in two. And when they applied a plumb-line to the buttress-pillars round the drum, or cylinder, of the dome, these proved to be as much as over an inch out of the perpendicular.

This naturally pointed to the over-pressure of the spheroidal portion, with the lantern above, upon the drum. But our three mathematicians were not satisfied with this simple deduction; they carefully examined the piers, to which popular judgment attributed the damage; and they found that judgment to be erroneous. The piers were intact, and required no attention. They therefore advised that nothing should be done to them. Thus having formed the hypothesis of over-pressure, they proved that every phenomenon, to the slightest crack, fell into it, and was adequately explained by it, and by no other.

Their next step was to verify most exactly the reality of what they had theoretically ascertained, by weighing, on the one hand, the materials supported, and measuring, on the other, the sustaining power. I will not detain you with details, which are minutely given in the original memoir, but present to you the general results. Having exactly weighed measured portions of the materials used in the construction of this wonderful building—the stone, brick, copper, lead, and iron—and then, from accurate plans, and by sound calculations, having measured the quantity of each, they found that the entire dome, with its lantern, came to the frightful weight of 165,000,000 of Roman pounds, or 55,245 tons.

They obtain separately the weight of the gravitating portion, and then calculate the resistance or supporting powers. This consisted, first, in the drum (*tamburro*), with its pillars thrust already out of the perpendicular; and secondly, of an iron girder, too slight for its purpose, but so embedded in the wall that it could not be examined. They estimate, however, its tenacity, and take it into reckoning; but conjecture that it had either snapped or dilated, so as to be useless.

But they thus reached the awful result—that there was a balance of 5,000,000 pounds, or 1,674 tons, on the side of pressure against support. The conclusion of the mathematicians was that "an irreparable ruin was reasonably to be apprehended unless a timely and efficient remedy were applied."

We may well imagine the alarm of Rome, with its artistic population, at such an announcement as this; and at hearing that this collapse and ruin had only been prevented so far by an iron collar round the base of the lantern, and by the peculiar construction which united the double dome to this, so as to prevent its falling out.

It is easier to find a defect, and prognosticate misfortune, than to remedy the one or to avert the other. But the commission to the three mathematicians was not only to probe the evil, but also to suggest its "efficient cure," which they consequently proceeded to do.

Well, what sort of remedy did they suggest? One entirely scientific, and not a little appalling. It was to put six more solid girders round this huge periphery of 420 feet. Each, of course, was to be divided into several sections, or arcs; and where these met, each had to branch into three; and these branches proceeding from the two arcs were to be fastened by bolts passing through sockets in them; the bolts again being riveted to chains passed round the building. A

gigantic or Cyclopean undertaking; for you must remember that there were then and there no Nasmyth's hammers or Birmingham rolling-mills; so that the enormous hoops had all to be forged and shaped by hand.

Of course, no sooner had this report appeared than it was assailed in all its parts—groundwork, deductions, and proposals. To vindicate it, and reply to the objections so gravely urged, and, at the same time, give an account of further proceedings in the matter, a second memoir was drawn up by the same learned men, early in the following year. A meeting of the general committee was then held, comprising architects, antiquarians, and others. A fresh examination was made; and finally the decision of the "three mathematicians" was adopted, and their proposal accepted.

There was no time to be lost, and no time *was* lost. Before the end of that year, 1743, two girders were braced round the drum. In 1744, three more were added. According to Poleni, their weight amounted to 119,044 Roman pounds, or 39 tons.

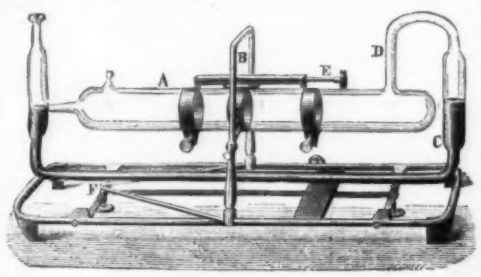
In 1747 it was found that the "mathematicians" had conjectured rightly, that the girder put in under Sixtus V. had sprung; and another was substituted for it. These iron circles are not visible, but are embedded in the stonework.

We have here a notable instance of science coming to the succor, or rather to the rescue, of art, in one, certainly, of its most painful crises. One knows not which most to admire: the sagacity which at once recognized the power that was needed and called it in, or the free and unlimited scope given to its exercise, or the sensible acquiescence of the artistic commissioners, or the sound judgment of the scientific deputation, or finally, the complete success of its remedy.

Without this all else, and a vast expense, would have been wasted. But the proposed cure fully answered; and now, after 120 years, no sign has been given of subsequent damage; but the seals, or dovetails, placed over the former fissures, left purposely open, are unbroken and unmoved.—*London Architect.*

A NEW FIRE ALARM.

THE annexed figure represents an apparatus for closing the circuit of an electric fire alarm by means of the expansion of air and the action of gravity. It consists of a glass cylinder, A, full of air, and mounted upon pivots in a frame, B, in such a way that it can tilt in one direction or the other like the beam of a balance. A glass tube, C, containing mercury is arranged parallel with the cylinder and connected with it. One of the extremities, D, of the glass tube communicates with the air chamber, so that the mercury in the column, C, of the tube rises or falls according as the pressure of the air in the cylinder, A, increases or diminishes. The position of the cylinder in the frame is variable, through the screw, E, so that the equilibrium of the system can be regulated at will.



A NEW FIRE ALARM.

When a fire breaks out and increases the temperature around the apparatus, the air expands in the cylinder and causes the column of mercury in C to fall; the equilibrium of the balance is destroyed, and one side of the apparatus descends until it touches the two contact springs, F. The electric circuit is thus completed, and sets in operation an electric bell or an indicator. The temperature at which the apparatus is to operate is determined beforehand, and the balance is regulated in consequence. The tubes descend with sufficient force to establish a perfect contact, provided the platinum points are clean. The apparatus returns to its normal position automatically as soon as the temperature falls and the mercurial column rises. The inventor of this apparatus is Mr. Pritchett.—*La Lumiere Electrique.*

JABLOCHKOFF'S AUTO-ACCUMULATOR.

MANY of our readers will remember that a few weeks ago we described, under the title of "Jablochkoff's Auto-Accumulator," a very novel and promising form of electric battery. The inventor, whose name is known wherever the fame of the electric light has penetrated, is now in this country, and we are in a position, from personal observation, both to corroborate our former notice, and at the same time to supplement it by a sketch of the theory upon which the battery is supposed to operate, and by a more detailed account of the apparatus itself. The two electrodes are hydrogen and oxygen; the former is produced according to the well-known reaction, by the oxidation of a metal, such as iron or zinc, and the latter is taken from the atmosphere, and occluded in the pores of pieces of opened grained carbon. This latter circumstance is sufficient of itself to impress the battery with the stamp of originality. It has long been known that carbon has the power of absorbing many times its own bulk of gases, and this quality has been taken advantage of to some trifling extent for sanitary purposes, but the idea that carbon might thus be made to act the part of a vehicle to transform the oxygen of the atmosphere into a condition in which it may be used as a battery pole has never, we believe, been mooted before. The hydrogen is likewise deposited upon a carbon plate, which is saturated with paraffin wax to render it perfectly dense, and prevent it playing the same part as the neighboring plate, viz., that of absorbing oxygen. Thus we have two surfaces of carbon, one charged with hydrogen, and the other with oxygen, and these constitute the electrodes of the battery. If they be connected by a fluid medium, and coupled by a metallic circuit, a current of very considerable intensity is found to flow round the circuit, the oxygen and the hydrogen gradually combine, and the action continues until the supply of one or other of them is practically exhausted. Then, if the circuit be broken, a recuperative process immediately commences; the hydrogen is evolved from the metal, and attaches itself to the one carbon plate, while the other electrode fills its molecular interstices again with oxygen, which will be drawn out again when the electric current commences to circulate. And so the process goes on, action following rest and rest following action, as long as the supply of metal is not exhausted, and there remains the small quantity of moisture required for its oxidation. Thus we have an accumulator in which the chemical process is not brought about by a current of electricity from an external source, but by the chemical changes in the battery itself. Hence the name given to it by M. Jablochkoff, "the auto-accumulator."

It will be seen at once that a battery to carry out this principle of action may be made in many different forms. Those at present constructed consist of shallow trays of carbon, 4 in. by 4 in. by ½ in. measured externally. Within each tray there is a small quantity of zinc filings or cuttings, covered with a layer of coarse cloth saturated with a solution of chloride of calcium, and bearing on its upper surface some half-dozen tubes of porous carbon. These tubes are about ⅜ in. in external diameter, and lie side by side in the tray, the tubular form being adopted to expose greater surface to the air, and to afford complete access to all parts. If plates were used, the lower surface would be sealed against the wet cloth, and the air could only act on the upper side. The two poles of the cell are the carbon tray and the carbon tubes. In making up a battery the cells are piled one above another, the tray of one cell standing on the tubes of the cell below it, and thus all the elements are coupled in the proper order, positive being connected to negative, and negative to positive, all through the series. The lowest cell stands on a metal base, and over the upper cell there is placed a plate of carbon which is screwed upon the tubes, and binds the whole column firmly together.

Many parts of the combination can be varied at will. The metal which effects the release of the hydrogen from the water can be zinc, iron, sodium, or any other that is easily oxidized. It is curious, however, to note that the electromotive force of the battery varies with the metal used, some materials giving much better results than others. In our former notice we published the following table of electromotive forces, and which has been fully confirmed by subsequent experiments:

	Volts for each Cell.
Iron	1·1
Zinc	1·6
Sodium amalgam	2·2

This would appear to point to the fact that it is not the hydrogen which forms the pole of the battery, but the metal. It can be shown, however, that this view is wholly incorrect, because, when a cell has been charged, the tray may be washed out to remove all the metal, the cell put together again, and after that it will be found that a powerful current is given off. M. Jablochkoff explains the variation on the hypothesis that the electromotive force of a hydrogen and oxygen couple varies with the degree of density of the materials, and that if the hydrogen were used in the metallic state and the oxygen as a liquid it would reach a figure corresponding with that deduced from the heat of combination. It is very probable, he argues, that hydrogen prepared in different ways will be deposited in or on the carbon plate to a different degree of density or compression, and that consequently it will, in some cases, be nearer the metallic state, although a very long way distant, than in any other cases, and that, therefore, the couple will give rise to a different electromotive force. This view is, to some extent, borne out by the fact that the metals which give rise to the most rapid evolution of hydrogen also give the greatest electromotive force in this battery.

The liquid medium of the cell may consist of almost any fluid capable of conducting electricity, accompanied by some material which will support the weight of the upper electrode. A solution of chloride of calcium has the advantage that it constantly absorbs moisture from the air, and thus does not readily become dry. It may be used with canvas, cotton wool, sawdust, paper, or any absorbent non-conducting substance which will intervene between the two electrodes. Another substance which has been used is gelatinous silica, prepared by adding hydrochloric acid to silicate of potash. This forms both a fluid and a supporting medium for the carbon tubes.

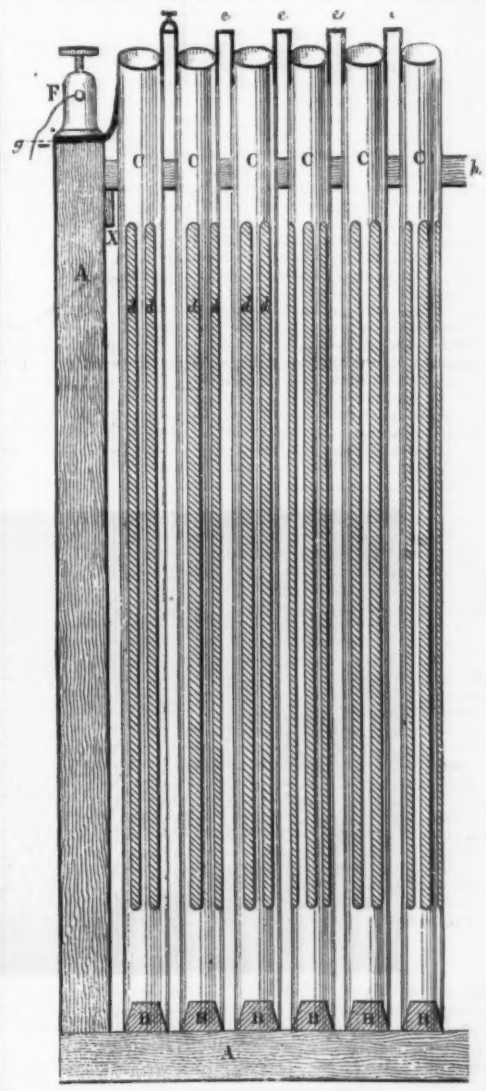
The oxygen absorbing electrode, the salient feature of the whole battery, and the one around which the principal interest gathers, has been the subject of very long and patient experiment to bring it to its present state of perfection. Any kind of carbon will absorb oxygen to some extent, but as the size and weight of the cells must vary inversely with the amount of oxygen which can be stored in a given mass of carbon, it follows that the price and portability, if not the practicability, of the battery must vary with the storage capacity. The tubes are prepared from finely divided coke mixed with other material which will be destroyed in the baking process, and leave the spaces occupied by it free to be penetrated by the atmosphere.

The current produced by a cell when short-circuited varies from 3 to 4 amperes, which, with an electromotive force of 1·6 volts, equals an energy of 4·8 to 6·4 watts. When the external resistance is about equal to the internal resistance of the battery, the current is maintained for a quarter of an hour before it shows a sensible drop, but it will last for nearly an hour without any very great diminution. When five cells are joined in series to a five-candle lamp, it is at once incandesced to its full power, and at the end of an hour the filament is still bright red, although it does not give any sensible light. An interval of a few minutes is sufficient to restore the battery to a point at which it will again bring the lamp to a fair illuminative power, although not of course to the original point. It has not yet been determined what proportion the rate of charge bears to the rate of discharge, but it is certainly as fast, and it appears as if it were faster.

It is somewhat difficult at this stage to speak definitively of the future of this battery, but this much at least is certain, that it appears likely to displace very many that enjoy a considerable popularity. Its advantages are evident even to those who have no technical knowledge of electricity. The total absence of all fumes and acid liquors, the freedom from corrosion consequent upon there being no metallic connections between the cells, the immunity from "creeping," and the permanent nature of the tray, appeal at once to all who have ever used batteries for ordinary purposes, such as ringing bells, working telephones, and the like. But the inventor has more ambitious views than this, and looks more particularly to the production of motive power as a field for his battery. There is a very genuine demand for a domestic motor, one that will be cheap, although not necessarily as cheap as the steam engine, and it is toward this end that he is working. He calculates that an electrical horse power can be produced for about one halfpenny per hour if the metal used be iron, and that after all the incidental losses peculiar to small motors had been added, the cost would still be insignificant, and within the means of the ordinary householder. Domestic lighting is another purpose which will occur to every one as a field for this battery, and the one for which it would find the largest opening in this country. To whatever use it is applied, however, it needs that there shall be a double set of apparatus, one to be resting and recuperating while the other is at work, and a self-acting switch to effect the exchange of the two automatically at short intervals. From time to time, of course, the battery must be cleared, the zinc salt must be washed out and the cloths rewetted, but the process involves no handling of acid, and is within the comprehension of the most unscientific person. Altogether the invention starts with the fairest promise, and there is every reason to believe that it has a wide future before it.—*Engineering.*

GIME'S ACCUMULATOR.

MR. E. GIME'S accumulator is based upon the principle of Faure's apparatus, but totally differs from the latter in construction. As may be seen in Fig. 1, it consists of a receptacle, AA, made of oak lined with a thin layer of gutta percha. Upon the bottom are arranged some cones, which are designed for holding the leaden tubes, CCC, in a perfectly vertical position. A cover, perforated as shown in Fig. 2, helps to do the same thing. This cover rests by its edges upon a ledge, X, that runs round the interior of the receptacle. The tubes, CCC, the number and dimensions of which are unlimited, are provided with longitudinal slits, *dd*, and are arranged quincuncially, so as to present, as a whole, no open space. Each line of tubes is connected either with a conductor placed permanently upon one of the sides of the receptacle, and formed of a strip of copper, or with a pliant conductor or a charge or discharge rheophore. It will be remarked that each line of positive tubes is formed of one tube less than the negative line. This is a natural consequence of the quincuncial arrangement. The tubes are connected with each other by springs, *e*, *e*, *e*, of a width less by 0·04 inch than the space between them, and which act with a friction that effects a perfect contact. The tubes are filled with sulphate of lead, which the inventor finds



GIME'S ACCUMULATOR.

preferable to red lead for this purpose. The liquid is water with the addition of a tenth part of acid.

It will be seen from the arrangement of this accumulator that it is always easy to replace a used-up tube; it being only necessary to remove the two springs that connect it with its neighbors, take out the tube, and slide a new one into its place.

But a single type of the apparatus has been constructed, and that of 220 pounds for fixed installation. The formation requires 120 hours, and its electromotive force at the discharge is from 3 to 3·5 volts.

The rendering is 95 per cent. of the electricity stored up, admitting, however, a loss of 10 per cent. of the potential, that is to say, an element that has stored up a quantity of electricity equal to 750,000 coulombs will render 712,975 coulombs at the discharge, but that the potential, which at the charge was 100 volts, will be but 90 at the discharge.

The practical capacity of the accumulator is 9,880 foot-pounds per pound of lead. But if it be desired to allow the accumulator to become depolarized and to discharge it anew four or five hours afterward, it will be easy to raise the quantity furnished at the discharge to 12,190 foot-pounds per pound of lead of the accumulator.

According to the inventor, this accumulator recommends itself by reason of the simplicity of its construction, its large rendering, its slight wear, and the ease with which it can be put together and taken apart without lowering the charge or discharge current, since the lines of tubes are independent of each other, and are connected for quantity.—*La Lumiere Electrique.*

THE FORMS OF VIBRATING BODIES.

M. C. DECHARME, whose very ingenious experiments to render visible or to simulate vibratory or molecular motions we have noticed from time to time, has now devised a method of making apparent the forms which bodies take when vibratory movements are impressed upon them. To reveal the elementary forms M. Decharme employs, as his agent, a liquid to which the vibrations of the solid body are communicated, and which, in consequence of its great mobility, takes up a position which represents the dynamic state of the surface with which it is in contact. But, in general, the effects produced by the movement of the body experimented on, in ordinary conditions, are so fugitive that the observer has not time to examine them with all the care he would wish to bestow upon such a delicate investigation. It is necessary, in order that these appearances may be duly considered, that the vibratory state should be more lasting, remaining constant the whole time.

To attain the desired continuity, M. Decharme availed himself of electricity as a motive power. This was not the first time that this agent had been employed for the purpose. M. Mercadier had already made the attempt to produce the vibrations of a diapason and of steel springs. But when the experiment is carried out with plates of brass, or glass, or of any other non-magnetic substance, the arrangements need to be entirely changed to meet the altered conditions. In the experiments we are about to describe the plate, P (Fig. 1), of a uniform thickness, is pierced with a central hole about a quarter of an inch in diameter, and is fixed at that point upon a very heavy foot by means of a screw, small leather washers being placed at each side of the plate. Upon the plate there is fastened a small disk, *d*, of soft iron, and below this there is arranged an electro-magnet. There is soldered to the disk a steel or platinum wire, *f*, four-tenths of an inch long, and arranged to come in contact at each upward vibration with the contact screw, *p*. The electric circuit passes through the coil of the magnet, E, thence through the fine wire spiral, *f'*, to the disk, *d*, and by the circuit breakers, *f* and *p*, to the terminal at *e*. The electro-magnet can be adjusted both vertically and horizontally to suit different kinds and sizes of plates. In using the apparatus the contact screw is first brought into contact with the point upon the plate. The circuit is thus completed, the electro-magnet becomes excited, and the plate is attracted. Immediately it commences to move the contact is broken, the current is interrupted, and the plate rises by its elasticity; a new contact then takes place, and so on. The vibratory movement thus continues with an amplitude that can be regulated either by varying the distance of the magnet from the iron disk which acts as the armature, or by altering the number of cells in the battery. Of course other forms of contact breakers besides the one shown in the illustration can be used for the purpose.

When the plate is of steel, it is easy to concentrate the attractive action upon a point. But if it be of brass, bronze, or glass, this is no longer the case; it is then necessary to give to the armature which is attached certain dimensions, in order that the magnetic force may have sufficient power. In these conditions, in order to concentrate the attractive action in the smallest possible space, it is better to substitute for the disk a small narrow plate, arranged radially. In such case a magnet of two branches with rectangular polar faces will be used. The attraction may be increased by using two magnets arranged at the two extremities of a diameter of the disk, and acted upon by the current alternately. Whatever arrangement be adopted, there must be a disk or armature at each extremity of the same diameter in order to balance the plate.

In carrying out the experiments the disk is first leveled, and then the edge is furnished with a rim of modeler's wax. Within the area thus inclosed a layer of water is spread varying in thickness from one to three millimeters according to the effects desired. In place of throwing the plate into vibration by means of a fiddle-bow, as in the ordinary acoustical experiments, the electric current is brought into play, and produces without shock the continuous vibratory movement of the plate and the liquid. There appears on the surface of the latter symmetrical chequered networks or systems, more or less extended, sometimes disposed on the periphery, and sometimes completely detached from the edges. When these systems are examined attentively, they are found to consist of a multitude of curved or rectilinear striæ, sometimes oblique and sometimes perpendicular to each other, arranged either in parallel bands or in regular chequers, having a beautiful effect.

Every one is acquainted with the acoustical figures of Chladni, in which fine sand arranging itself on vibrating plates represents the lines of repose, the nodes, which are sometimes radial, and sometimes concentric circles. By the method we are describing it is the moving or ventral portions of the plate that are represented by the liquid. The accompanying figures show the correspondence between the two opposite effects; Figs. 2, 3, and 6 illustrate the peripheral system, Figs. 4 and 5 the eccentric systems of the first order, and Fig. 7 those of the second order. The systems of the same kind have the corresponding nodes for their rigid limits. Borrowing a comparison from the phraseology of photography, that the ventral systems are the positives, and the nodal systems the negatives of one another. As to the striæ flutings which compose these systems, they are the elementary nodes. M. Decharme has investigated the means by which systems of different kinds may be produced at will, and has demonstrated their correspondence with the acoustical figures of Chladni. He has also determined the mathematical relations which exist between the number of systems, the size of the striæ, and the numbers of vibrations in the corresponding sounds. These, however, are considerations which we shall pass over, confining ourselves to the forms which the vibratory surfaces exhibit, when the experimental conditions upon which they depend are made to vary.

In the first place it must be noted that the peripheral systems, corresponding to the low notes of the plate, can exist separately to the number of 4, 6, 8, and 10. Thick plates give none other than these, while the eccentric systems, which only begin to appear with the high notes when the plate divides in six sectors at least, are always accompanied by peripheral systems situated in the same sectors; only these latter systems can be considerably reduced at the side near to the center when they are numerous. The peripheral system, when occurring alone, approximate to the semicircular form (Figs. 2, 3, and 4), while the eccentric systems are elliptical (Figs. 5, 7, and 8), their major axes being per-

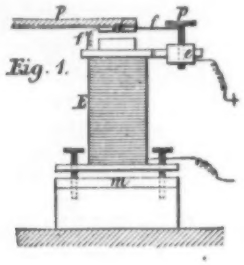


Fig. 1.

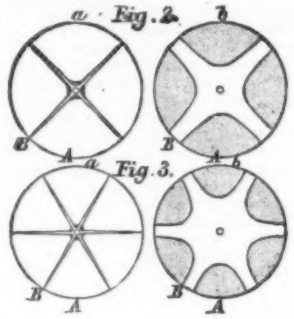


Fig. 2.

Fig. 3.

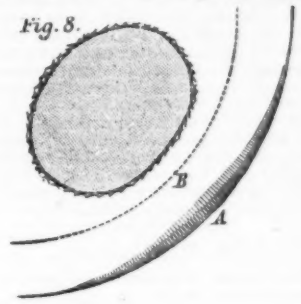


Fig. 8.

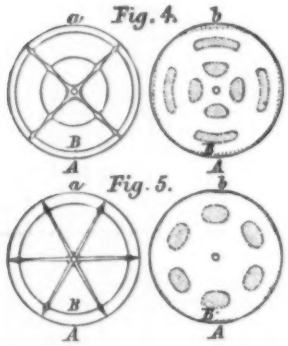


Fig. 4.

Fig. 5.

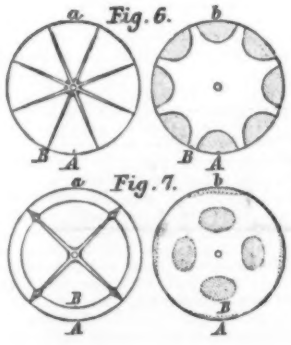


Fig. 6.

Fig. 7.

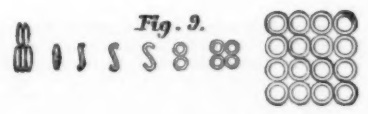


Fig. 9.

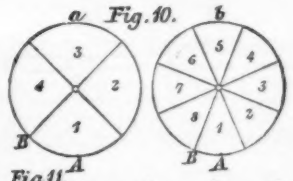


Fig. 10.

Fig. 11.

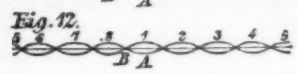


Fig. 12.

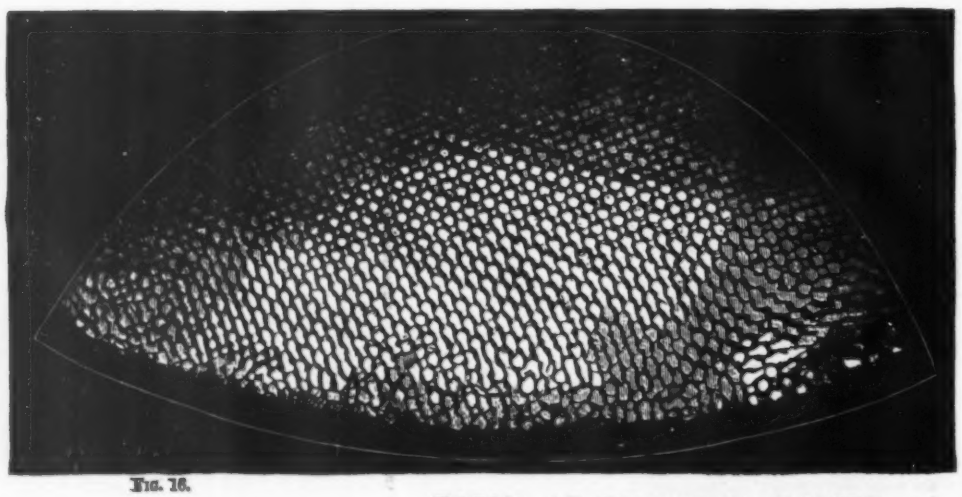


Fig. 16.

Fig. 13.

Fig. 14.

Fig. 15.

FORMS OF VIBRATING BODIES.

pendicular to the radii of the plate, and the centers of their figures for each order being arranged upon a common circle concentric with the circumference of the plate. There can be two or three rows of eccentric systems between the two or three concentric nodes (Figs. 6 and 7). All the systems which are completely developed are checquered. For all the simultaneous systems, peripheral or eccentric, the size of the striæ is the same and the structure appears identical, which is very natural, seeing that all the parts of the plate vibrate in unison, at least for the dominant sound which is observed.

The subject of most interest in the study of elementary vibratory forms is the evolution of the liquid striæ, that is, the successive changes which the first ripples experience as they attain by degrees the final reticular configuration. The acoustical figures of Savart, while showing the lines of positions of the nodes, give no clew to the elementary vibratory forms of the plates. The liquid, on the contrary, in a thin layer reproduces with great distinctness the smallest movement of the vibrating plate, and exhibits perfectly the contours of the surfaces in movement, particularly those which are produced at the edges. The very finest striæ, which are only a fraction of a millimeter in extent, are depicted upon the water with extreme and captivating delicacy. Chladni was delighted at the sight of the figures produced by sand upon vibrating metal plates, figures which no one, he said with a certain pride, had ever seen before him. If he had been able, remarks M. Decharme, to observe the delicate and incomparable waves of water, alcohol, and mercury upon a vibrating plate of glass, he would have been far more astonished. That which cannot be portrayed, which escapes both graphic and verbal description, is the peculiar movement, the trembling of the liquid, its evolutions in arriving at the form of intersecting waves, which at first occur only at the circumference, then reach forward in symmetrical points, a kind of leaves of which the extremities are as delicate as if they were stippled. These waves cover almost the entire plate for the fundamental sound, and raise themselves at their edges in conical billows above the level surface, or even detach themselves in small drops which roll themselves toward the center, or fall outside.

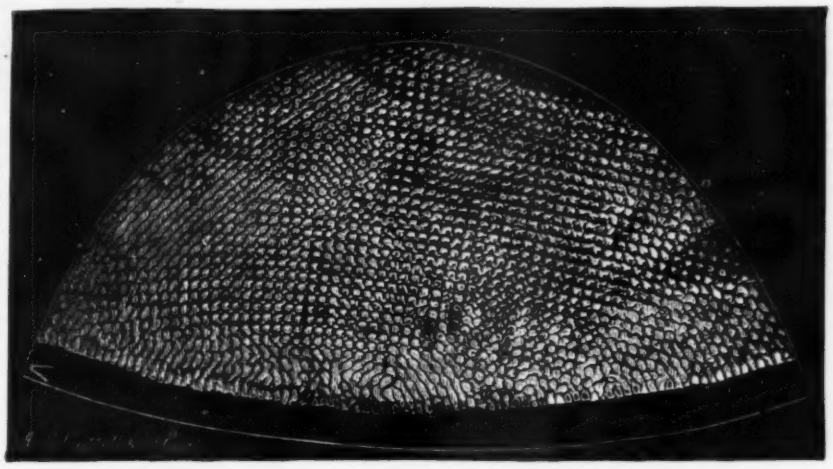


FIG. 17.

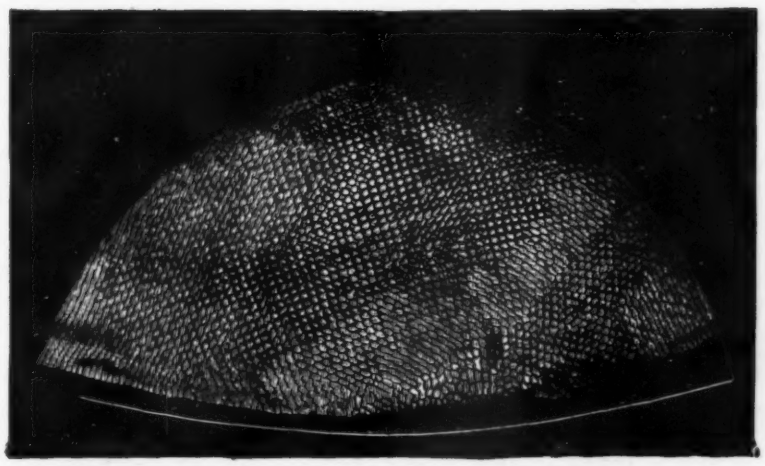


FIG. 18.

FIG. 19.

FORMS OF VIBRATING BODIES.

In order to give an idea of the general form of these waves, so varied in their evolutions, even for a single sound, let us suppose that the experiment is made with a thin plate covered with a layer of water from 1 to 3 millimeters in thickness. The plate is first acted upon by a very feeble electro-magnetic attraction in such a way that it gives out its fundamental tone; no ripple appears on the surface. As the attraction is made to increase, there are formed, at four, opposed points, simple channels, often in a single row, occupying almost the whole circumference of the plate. They are rather more than a centimeter (0·4 in.) in length, are in radial directions, quite contiguous, and of a width of about two millimeters ($\frac{1}{12}$ in.). As the attractive energy is progressively increased without any change being made in the height of the return, these long waves experience a sensible torsion, and appear animated with an oscillatory movement, which gives them the form of sinuous waves of S shape, more and more closed (Fig. 9). Then there is observed in the channels which are nearest to the center of vibration a segmentation of two or more other channels more elevated than the first. Next parallel striæ are seen among the others, sometimes in fairly regular curved lines, sometimes in sinuous lines, then in chequered systems where the marginal channels are still to be distinguished, but diminished in length, more or less twisted, and a quincunx of intersecting waves, sometimes oblique, and sometimes perpendicular to one another, but approaching the more to this latter disposition in proportion to the regularity of the system, the size of the flutings remaining constant if the sound does not change its note. The extremities of the system often resemble lanceolated leaves of surprising delicacy; these dying waves, as it were, are only the shadows of the striæ at the circumference. At length, when, under a sufficiently energetic action, the systems arrive at their complete development, they invade almost the entire surface of the plate. If the experiment be pushed further, the liquid, violently shaken, detaches itself in spherules, of which some roll to the center and the others leap off the plate. When the electro-magnetic excitation has ceased, the systems repass, in an inverse order, through the same phases which they followed in their development.

After the fundamental tone which determines the division of the plate in four vibrating sections, the sound which follows most easily and sometimes spontaneously is that which corresponds to the division in six equal parts. For this tone and for those which follow, the same evolutions of striæ present themselves, but they are more and more difficult to observe on account of the smallness of the channels. But in examining attentively the form of the complete systems, in each case there is found the same disposition which was easily recognized from the fundamental sound. The evolution of the eccentric systems is yet more difficult to follow than that of the peripheral systems. An energetic action shows these striæ arranged perpendicularly among themselves, and the contours of each system are clearly limited in a circle or an ellipse by curves turning their convexity toward the interior of the system. These lines form by their numerous intersections a sort of enveloping curve which gives to the whole a well-defined form (Fig. 8).

Production of the Liquid Systems.—To explain the production of the chequers constituting the system, it must be admitted that they are the faithful representations of the vibratory forms of the subjacent parts of the plates. From this point of view the striæ represent the nodes of vibrations, and may even serve to determine the wave length of the corresponding sounds. It must be remarked that in a plate, as in other vibrating bodies, the two kinds of vibration, longitudinal and transversal, co-exist; the one, however, can control or efface more or less completely the others, according to the experimental conditions.

Let us suppose that it is desired to represent the vibrating state of a plate under experiment. For that, let it be assumed that its gives its fundamental note, which divides it into four symmetrical sections, A (Fig. 10*a*) being the point acted upon, and B the fixed point. The sector 1, supposed to vibrate from above downward, communicates to the neighboring sectors, 2 and 4, a movement from below upward, and these in their turn transmit it, in the opposite sense, to No. 3. These four portions of the circle always rotate in unison, since they are equal, and their movements correlative, but they preserve their differences of phases. So when the plate divides itself in eight (Fig. 10*b*) the movement is transmitted from sector 1 to sectors 2 and 8, and from these to 3 and 7, then to 4 and 6, and lastly to 5. All these portions vibrate in unison. Independently also of the general movement each sector divides itself, after the manner of a chord, into elementary vibrating sectors, which show themselves as channels arranged radially, and disposed first at the circumference, then extending toward the center.

But it is known that a body cannot vibrate energetically in one direction without at the same time vibrating in a direction perpendicular to the first. Figs. 11 and 12 represent the development of the circumference of a plate divided successively into four and eight sectors. When systems are produced detached from the edge, and arranged in one or more rows, the bending is more marked, following circles concentric with the circumference of the disk. Figs. 13, 14, and 15 show in diametrical sections the vibratory state, for one, two, or three concentric nodes. In these figures the vertical scale is exaggerated, in order to render the sinuosities more apparent.

In conclusion it may be said that the two systems of vibration always co-exist, but that the one can control or efface the other, according to the mode of excitation and of the mounting of the disk. Thus all the peculiarities of the phenomena are explained on the assumption that the liquid systems represent the vibratory form of the subjacent portions of the plate. In order to render permanent the forms which he produces, M. Decharme mixes with the liquid minium or some other heavy insoluble powder. This arranges itself upon the plate, receiving the vibratory movement of the subjacent portions and translating it into the forms of systems more or less delicate and regular. By stopping the current, and leaving the plate to its natural vibrations, which soon die away without shock, the minium disposes itself in flutings and chequers, and preserves in elevation the forms which the liquid assumed in its dynamic state. After the water has been carefully removed, and the plate has been dried, the dry minium remains fairly adherent to the plate, which can be made to serve as a photographic negative. Figs. 16, 17, 18, and 19 have been obtained by this process. They represent the reticulated deposits of the peripheral systems of the same plate divided successively into 4, 6, 8, and 12 sectors, and show the method of transformation or of evolution of the flutings in the systems. There are seen, near the edge, channels more or less sinuous which lengthen and then divide; further on there are seen undulating lines parallel to one another, also lines which cut each other, some perpendicularly and some obliquely, in such a way as to form regular quincunxes, composed of small rings, some completely closed, and some more or less open.

We are indebted, says *Engineering*, for this account of M. Decharme's experiments to a paper contributed by him to *La Lumiere Electrique*.

[JOURNAL OF THE SOCIETY OF ARTS.]

ON THE CONVERSION OF HEAT INTO USEFUL WORK.*

By WILLIAM ANDERSON, M.Inst.C.E.

LECTURE I.

THE object of the course of lectures which the Council of the Society of Arts has done me the honor of asking me to deliver, is to lay before you the modern views connected with the conversion of heat into useful work.

The subject is a very wide one, and, if thoroughly treated, would lead us into more branches of physical science than we have time to pursue. I must, therefore, restrict myself as much as possible to those examples of conversion of heat into work which are most useful to mankind, and with which practical life brings us into most frequent contact.

It is only within the last hundred years that the true nature of heat has been gradually explained. The experiments of Count Rumford and Sir Humphry Davy proved that heat was not a material substance, because it was capable of being developed to an unlimited extent by the application of external work, without any alteration in the weight or chemical composition of the

* Lectures recently delivered before the Society of Arts, London.

substance from which the heat appeared to emanate. This was a great step in advance, and it was followed by one of equal importance, when Joule, Coulding, Mayer, and others demonstrated experimentally that a given quantity of heat was always equivalent to a corresponding amount of work, and the almost necessary deduction which followed, namely, that heat was a consequence of the transformation of the coarse, visible motion of mechanical work into the invisible motion of the molecules of a body or the undulations of the mysterious medium, pervading all nature, through which are propagated the rays of light and radiant heat.

Gradually, likewise, it came to be perceived that there was a relationship between heat and certain other phenomena, such as light, electricity, and chemical action, and we have at last been able to establish, by the irrefragable evidence of experiment, that these manifestations are forms of energy convertible, for the most part, into each other, and all having a mechanical equivalent.

As I wish to impress you with the conviction that the relationship between heat and mechanical energy is not a vague generalization, but is a connection amenable to mathematical investigation, I must, in the first place, remind you briefly of the laws of motion, because, unless I do so, there is some danger that my arguments hereafter may not be understood.

We are indebted to Sir Isaac Newton for the first clear exposition of the laws of motion, and so complete was the conception which that great man had of these laws that his definitions, formulated two hundred years ago, cannot be improved even at this day, and some of the consequences hidden in them have only been discerned, or at any rate appreciated, in quite modern times.

According to the first law of motion, "every body continues in a state of rest or of uniform motion in a straight line, except in so far as it may be compelled by impressed forces to change that state." You will readily grant the first portion of this law, namely, that a body will remain at rest so long as something does not make it move; but the second portion is not so obvious, because we have no experience of it on the earth. We know by observation that anything set in motion and left to itself will sooner or later come to rest, but we also know that by reducing friction and the resistance of the air motion may be greatly prolonged. A boy, starting with the same impetus, will slide farther on ice than on a polished wooden floor; a carriage with well oiled axles will run farther with the same push than when its axles are neglected; a top will spin longer in a china cup than on a gravel path, and longer still under the exhausted receiver of an air pump. Generally, we know by experience and experiment that the more completely we remove the obstacles to motion the longer will motion continue when the impetus has once been given, and it would not be unfair to argue that if the obstacles could be removed altogether, motion would never cease.

On our earth we cannot accomplish this, but in the motions of the earth itself and of other heavenly bodies we see a proof of Newton's law. They have moved for ages, and will continue so to move under the influence of an impetus once given, their paths or orbits being traced through space in submission to the other laws of motion.

The second law of motion tells us that "change of motion is proportioned to the impressed force, and takes place in the direction of the straight line in which the force acts." You are to note here that a force always produces an effect, and that by the word "motion" you must understand the "quantity of motion," or "momentum," which takes into account not only the velocity but also the mass of the body, and further, that one motion does not interfere with any other motion the body may possess or have imparted to it. This last statement may appear paradoxical, yet you will find that it accords with every day experience. You know quite well that it is just as easy to move in one direction as in another in a railway carriage running at express speed, or on board a swift steamer. You are not conscious that the tremendous speed with which you are moving in consequence of the earth's rotation, a speed equal to that of modern cannon shot, is interfering with your freedom of action in any way; but you may hesitate before you admit that a cannon shot fired horizontally on a level plain will strike the earth in exactly the same time as a similar shot simply dropped to the ground from the center of the cannon. The fact is, that the ultimate result of two or more motions taking place simultaneously, is the same as if the motions took place in succession. The circumstance that the cannon shot travels at the rate of 1,500 feet per second in a horizontal direction, does not in the least interfere with the ordinary rate of falling from the height of the cannon to the ground. I have here an apparatus (Fig. 1) by means of which I can project a

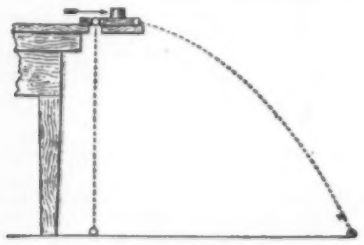


FIG. 1.

marble horizontally, and at the same moment allow another to drop vertically, by striking sharply the spring slide which holds one ball, thus releasing it, and projects the other horizontally. If I have adjusted the instrument properly, you will hear but one knock when the two marbles strike the floor; they will reach it in exactly the same time, though the path of one is so much longer than that of the other. Upon this law is founded the principle of the composition of motions which are taking place in two or more directions, under the influence of as many forces acting as angles to each other.

Suppose two equal forces tend to urge a body in two directions; the velocities will be equal, because the mass moved is the same and the pressure equal. Now, by the second law, the two forces do not interfere with each other, so that, taking a very minute period of time, we may suppose the motions to take place in succession, first along one line of motion till a certain point is reached, and then from that point in the direction of the other force and for the same time. Repeating this process, it will be found that the body travels along the diagonal of a parallelogram constructed on the two lines of motion.

If the velocities are unequal, the length of the lines representing the direction of motion must be made

FIG. 2.

proportional to the velocities; and if the velocities are not uniform, then the position of the body in equal times must be ascertained for each direction of motion, and the true place of the body found by supposing the motions to take place consecutively.

The unit of measure for momentum is the unit of mass of the body multiplied by a velocity of one foot per second. The weight of a body is a variable quantity, even on the earth, on account of the effect of centrifugal force due to the rotation of the earth, that is to say, a pound weight which will stretch a spring balance to one pound at the equator will stretch it over a pound at the poles. But change of motion being proportional to the impressed forced, it follows that the velocity attained in a second by the action of

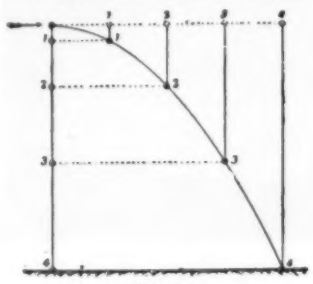


FIG. 3.

the weight of the body on itself, in falling freely, will be proportioned to that weight; hence the weight of the body, divided by the velocity per second it produces in itself in falling freely in one second, will always be a constant quantity in any place, and is called the mass, generally denoted by the letter M.

The weight of the body is usually called W, and the velocity it attains in falling freely *in vacuo* at the end of one second is invariably known as g; and therefore $M = \frac{W}{g}$. g is variable like W. In England it is taken approximately as 32·2 feet per second, or roughly as 32, so that the unit of momentum is $= 32{\cdot}2 \times 1$ foot per second.

Supposing a force of 50 lb. acts for one second on a weight of 10 lb., what will be the velocity at the end of the second? 10 lb., acting on itself as gravity for one second, produces a velocity of 32·2 feet per second; therefore a force of 50 lb. acting on a weight of 10 lb. will produce five times as much motion, or 161 feet per second.

A train weighing 200 tons attains a speed of 40 miles an hour, or 58⅔ feet per second, in a distance of two miles. What must have been the pull of the engine all the time to produce the result? We argue in the following manner: If the motion was uniformly accelerated, the average speed must have been 20 miles an hour, or one mile in three minutes; hence the two miles were traversed in six minutes, and the speed attained was 58⅔ feet per second in 360 seconds, therefore the speed gained was 0·163 feet per second. If the train had been pulled with a force of 200 tons, it would have acquired a speed of 32·2 feet per second; but, as it only attained 0·163 feet, the pull must have been so much less, or only a little over one ton.

According to the second law of motion, the circumstance that a force has produced a certain velocity in a second of time does not prevent the same force producing the same effect in addition, if it acts for another second, and hence we have the fundamental equation for motion produced by a constantly acting force $v = a\,t$; that is, the velocity v, at the end of any time t, is found by multiplying the velocity a produced in the first second by the time during which the force has acted.

The formula for connecting the space passed through with the time is not so simply arrived at. Suppose a body under the influence of a constantly acting force attains a velocity of 8 feet per second at the end of the first second, then it will have passed through a distance of 4 feet. In the second second, if the force had ceased to act, the body would, according to the first law of motion, have run over eight feet, but the force does continue to act, and to produce its full effect according to the second law of motion, and adds 4 feet more to the space passed over; hence $8 + 4 = 12$ feet will be described in the second second, which, added to the distance passed over in the first second, makes 16 feet passed over in two seconds, or the space passed through during the first second multiplied by the square of the time. At the end of the second second, the velocity will be $2 \times 8 = 16$ feet; therefore, in the third second, the space passed through would be 16 feet plus the addition of 4 feet per second, or 20 feet. Adding 20 feet to the 16 feet already traversed makes a total of 36 feet in three seconds, or 4×3^2, that is to say, the distance passed through during the first second multiplied by the square of the time; hence we have this well-known equation, for the space passed through in t seconds $S = \frac{1}{2}\,a\,t^2$, and by substitution we get

$$S = \frac{V^2}{2\,a}$$

$$v = \sqrt{2\,a\,S}$$

when a is the velocity produced at the end of the first second by the force.

By the aid of these equations, we can tell all about a body moving at a uniformly accelerated speed, if we know its final velocity, or the space passed through in a given time.

Take the case of the train, for example. What distance will the train travel to attain a speed of 40 miles an hour in 6 minutes? We have already seen that the pull of the engine communicated a velocity of 0·163 feet per second, which is therefore the value of a.

The time is 360 seconds. Taking the formula $S = \frac{a\,t^2}{2}$, we have $S = \frac{0{\cdot}163 \times 360^2}{2} = 10{,}562$ feet $= 2$ miles.

Cases of accelerating forces, that is, forces acting steadily for a time, are of common occurrence; in fact, no body can be set in motion, or have its motion changed, without the action of an accelerating force; nothing starts into motion suddenly, but always by degrees, and it is a matter of common experience that to move anything with increasing velocity requires more effort than to keep up a steady speed. The action of an accelerating force is usually illustrated by reference to gravity.

The attraction of the earth on a body near its surface is a constant force at the same place, and the velocity produced per second, 32·2 feet, is therefore made the standard by which the value of other accelerating forces is estimated. The principles I have explained apply equally to rotatory motion.

A fly wheel resists being brought suddenly into motion, or being suddenly stopped, just as much as a body moving in a straight line. But because the parts of a revolving body are moving at various speeds, it is necessary to find a circle in which the mean motion may be supposed to take place. This circle is called the circle of gyration, and its radius the radius of gyration. In a cylindrical disk, for example, the radius of gyration is equal to the radius of the disk divided by the $\sqrt{2}$. Having found the circle of gyration, the whole of the weight is supposed to be concentrated in it, and then the calculations are analogous to those for rectilinear motion. The circles of gyration, for bodies of regular shape, can be arrived at by calculation. In bodies of irregular shape it can be calculated when the position of the center of gravity is known, and the rate of oscillation about any point has been ascertained. The radius of gyration (r) is the mean proportional between the length of an equivalent pendulum (l) and the distance of the center of gravity from the point of suspension (c), therefore, $l : r = r : c \;\because r = \sqrt{l \times c}$. I have arranged a modification of a well-known contrivance, called Attwood's machine, to demonstrate the effect of a continually acting force like gravity, or the pull of a locomotive, commonly called an accelerating force.

FIG. 4.

At the top of this tall stand is a heavy brass pulley, round which is wound a thread, one end of which is secured to it, while to the other end is attached a small weight, a little over 1 oz., so proportioned that it will fall through one foot in one second. A brake, which I can release by this string, controls the motion of the pulley. On the face of the disk you see a black circle, which represents the circle of gyration. On the table stands a metronome beating seconds. I release the pulley; you see that the weight has fallen one foot during one beat of the metronome. I wind the weight up again, and let it fall through two beats; you see a space of four feet is passed through. Again, I wind up the weight, and let it fall through three beats of the metronome, and now nine feet have been traversed. I am thus able to demonstrate two things:

First, that the velocity produced on a given load by a force bears the same relation to the velocity produced in a body falling freely that the force bears to the weight of the load which it sets in motion.

The pulley weighs 1·95 lb. The circle of gyration is 4·24 inches diameter. One foot fall of the weight corresponds, therefore, to 0·707 foot described by a point in the circle of gyration, and therefore the velocity acquired at the end of one second is 1·414 feet. The load set in motion by the weight is its own weight, added to that of the disk concentrated in the circle of gyration. Calling the weight x lb., it will bear the same relation to the load 1·95 lb. $+ x$ lb. as 1·414 feet bears to 32·2 feet, the velocity acquired in one second by x falling freely by itself.

$$\frac{x}{1{\cdot}95 + x} \qquad \frac{1{\cdot}414}{32{\cdot}2}$$

$$x = 0{\cdot}09 \text{ lb.}$$

acting at the circle of gyration, or

$$0{\cdot}09 \times \frac{4{\cdot}24''}{6''} = 0{\cdot}064 \text{ lb., or } 1{\cdot}02 \text{ oz.}$$

acting at the periphery of the pulley.

Secondly, the apparatus demonstrates that the spaces passed through under the influence of a uniformly acting force are as the squares of the time.

When a body which is moving with a given velocity has to be stopped, the reverse action takes place; the force required to retard motion is exactly the same as that required to produce it, and, therefore, to stop a train of 200 tons weight going at the rate of 40 miles

an hour within a distance of two miles would require the brakes to exert an opposing push of one ton.

It follows from these considerations that the shorter the time or space in which motion has to be set up or stopped, the greater must be the accelerating force or pressure. In the case of one train coming into collision with another, the space is so short that the force increases to a point which shatters the carriages.

A rifle bullet can be stopped in about eight feet without injury to itself by being fired into bran; but fired against an iron target, the space in which the motion is stopped is so small that the retarding pressure rises to a pitch which completely destroys the bullet.

Newton's third law of motion is, "To every action there is always an equal and contrary reaction." This law applies equally to statical pressures and to momentum or quantity of motion. The reaction may consist of pressure, friction, resistance of the air, or acceleration; but whatever may be the nature of the reactions, the sum of their momenta is equal to that of the moving force.

The train we have already used to illustrate our reasoning will serve again. The power of the engine is resisted, we have seen, by a push of one ton due to acceleration. In addition to this, there is the friction of the axles and the rails, which may be taken at 10 lb. to the ton weight of the train, or 2,000 lb., and a variable resistance due to friction against the air, to the adverse pressure of parting it, and to the wind; all these together form the reaction to the action of the locomotive while the speed of 40 miles an hour is being gained. As soon as that has taken place, and the motion becomes uniform, the accelerating force ceases to act, and friction with resistance of the atmosphere alone remain, hence the work of the locomotive becomes much easier.

I have used the term "work" of the locomotive. This word requires closer examination. By the term "work" in mechanics is meant the force applied to a body multiplied by the space gone over in the direction in which the force is producing motion. The unit of work is one pound pull or pressure acting through a space of one foot, and hence called a foot-pound. The accelerating force of the train, for example, was one ton, or 2,240 lb., acting through two miles, or 10,560 feet, hence the work done in bringing the train from a state of rest to a speed of 40 miles per hour was 10,560 ft. × 2,240 lb. = 23,654,400 foot-pounds.

It is frequently more convenient to speak of the *rate* at which work is being done than of the total work performed. The unit of rate of work, for large quantities, has been taken as 33,000 foot-pounds per minute, and is called a horse-power. The work of getting up the speed of the train occupied six minutes; hence the rate of work was $\frac{23{,}654{,}400 \text{ foot-pounds}}{6 \text{ minutes}} = 3{,}942{,}400$ foot-pounds per minute, or, dividing by 33,000 foot-pounds, we get 119·4 horse-power which the locomotive exerted in producing the accelerated motion of the train.

In addition to the term "work," we have another expression, "energy," which means the capacity for doing work, and it is of two kinds.

"Potential," the power of doing work latent in an advantageous position. For example, the water in a lake high up among hills has a very different value from the same water fallen to the sea level, because, in the former case, it can, by its fall, be employed to do useful work; in the latter it cannot. The chemical constituents of coal and the oxygen of the air are the same after as before combustion; they are only differently arranged with respect to each other, and yet the products of combustion are valueless; while in the form of coal and air they are necessaries of life, because they form a store of potential energy. The heavenly bodies moving at uniform velocities for ever are instances of potential energy; they are doing no work so long as they are moving steadily; but if the motion of any one of them were opposed by some external resistance, its velocity would be diminished in proportion to the amount of resistance offered, and work would be given out. The steam pent up in a boiler, or compressed air, are also instances of potential energy.

The other form is that of "energy of motion," or "kinetic energy." Water falling and working a water mill is an instance of this; the action of steam on the piston of a steam engine, an animal drawing a load, etc. The sum of the potential and kinetic energies in any body is a constant quantity. Water that has fallen to the sea level has lost all the energy it may once have possessed; it has expended it in producing some kind of mechanical work. Suppose that we had an available fall of water of ten feet working a mill. Every 330 gallons falling in one minute would produce 330,000 foot pounds of work, or one horse power; hence the potential energy of each gallon of water is $\frac{1}{330}$ of a horse power. But after the water has passed through a well arranged motor, it flows sluggishly away to the sea, having yielded up nearly all its energy, in the form of energy of motion, to the machinery it was intended to bring into activity. But suppose that, from circumstances or bad arrangement, the water flowed away at a rapid rate, say ten feet per second; this would correspond to $\frac{10^2}{64{\cdot}4} = 1{\cdot}55$ feet of vertical fall; energy due to that height, therefore, remained in the water when it left the motor, and was wasted, making a loss of 15½ per cent.

When we know the weight and the velocity with which a body is moving, we can easily calculate its energy, or power of doing work. Take the case of a 6 inch cannon shot, weighing 100 pounds, leaving the muzzle of a gun with 1,500 feet per second velocity, acquired in a barrel 15 feet long; and let us further suppose that the motion in the gun is uniformly accelerated. Because 1,500 feet velocity was acquired in a distance of 15 feet, the velocity at the end of a second would have been, had the force continued to act, $a = \frac{v^2}{2 \times 15} = \frac{1500^2}{30} = 75{,}000'$, and the pressure to produce such a velocity would have been $\frac{100 \text{ lb.}}{32{\cdot}2} = \frac{x}{75{,}000 \text{ ft.}}$ $\therefore x = \frac{100 \text{ lb.} \times 75{,}000 \text{ ft.}}{32{\cdot}2} = 232{,}919$ lb., or nearly 104 tons. This would correspond to a mean pressure of 3·7 tons to the square inch of the powder gases, and the work done would been 104 tons × 15 feet = 1,560 foot-tons.

We can arrive at the result in a quicker manner. The shot starting from the muzzle of the gun, if directed vertically upward, would rise to a height $\frac{v^2}{2g} =$ 34,938 feet. If it fell from that height, it would do work equivalent to its own weight of 100 lb., which is the force impelling it multiplied by the distance fallen, or 3,493,800 foot pounds, equal to 1,560 foot tons, the same result as we obtained before; hence we have the general expression for the energy of a moving body $= \frac{W v^2}{2g}$ or the square of the velocity multiplied by half the mass. You must not confound energy with momentum or quantity of motion; the former has foot pounds for its unit, and varies as the square of the velocity; the latter has mass multiplied by one foot per second as its unit, and varies as the velocity.

Another illustration of the convertibility of potential and kinetic energy we have in a jet of water. A fountain having a jet ¾ inch in diameter is supplied by a reservoir 40 feet above the jet through a 3 inch pipe. According to well-known laws of hydraulics, the velocity of the water issuing from the jet will be the same as that attained by a body falling freely from the surface of the reservoir to the level of the jet, and we know that such velocity would be competent to carry each particle of water back again to a height equal to the level of the water in the reservoir. The velocity due to a height of 40 feet from the influence of gravity will be $8\sqrt{40} = 50{\cdot}56$ feet per second, and the kinetic energy of each pound of water issuing from the jet would be $= \frac{1 \text{ lb.} \times 50{\cdot}56^2}{64{\cdot}4} = 40$ foot-pounds. The potential energy of 1 lb. of water lying 40 feet above the jet is also 40 foot-pounds, so here we have a case of complete conversion.

But the area of the 3" supply pipe is 16 times that of the jet, hence the velocity of the water in it will be only 3·18 feet per second, and the kinetic energy of 1 lb. $= \frac{1 \text{ lb.} \times 3{\cdot}18^2}{64{\cdot}4} = 0{\cdot}15$ foot-pound; hence in any portion of the pipe the pressure will be less than that due to the column of water by 0·15 foot, because the sum of the potential and kinetic energies must be constant. This pressure represents the accelerating force which imparts to the water the velocity with which it moves in the pipe, and is called the "head of flow."

The cases of converging and diverging jets are instructive illustrations.

In a converging jet, the velocity of the water is constantly increasing, until at last, when it leaves the jet, it is evident that there is no pressure on the pipe at all, because the jet does not spread out laterally, all the

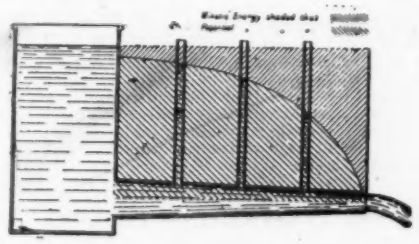
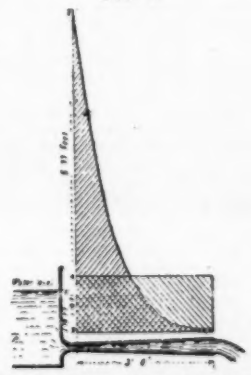


FIG. 5.

potential energy has become kinetic; hence, in a converging jet, the pressure on the sides of the pipe decreases continually, and the pressure at any point may be ascertained by deducting the kinetic energy at that point of the cone from the total potential energy.

In diverging pipes, when the enlargement of diameter is sufficiently gradual to permit of the fluid always filling the pipe, which it tends to do by reason of its viscidity and adhesiveness to the material the pipe is

FIG. 6.



LOWELL DIVERGING PIPE, J. B. FRANCIS.

made of, the velocity with which each particle of fluid moves must continually decrease, and its kinetic energy must also decrease in proportion to the square of the decreased velocity. The energy with which the fluid was endowed, as it issued from the narrow end of the tube, must therefore be converted partly into the potential energy represented by a tendency to push aside the atmospheric pressure against the open end of the tube, and partly to tear asunder the cohesion of the fluid, and break the stream up into slices. Both tendencies are manifested by an increased discharge from the pipe, for the atmospheric pressure, acting on the surface of the liquid above the narrow end of the pipe, augments the flow in proportion as the retardation of the fluid toward the open end cuts off the pressure of the atmosphere from that side. The whole of the conical tube is in partial vacuum from the large end backward, the vacuum, which represents the potential energy, increasing as the narrowed part of the tube is approached, on account of the great mass of water operating to balance the atmospheric pressure, and call into play the cohesive force of the fluid.

The phenomenon may also be explained in the following manner: Imagine the fluid in the diverging pipe to be cut up into slices, at right angles to the axis; then, because the motion is uniformly retarded, the

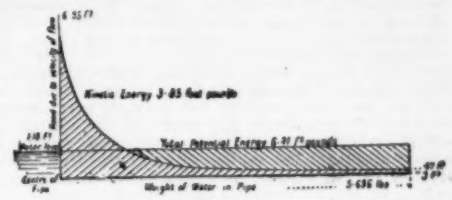


FIG. 7.

pressure on the front of each slice must be greater than at the back, and consequently the pressure in the narrow part of the tube must be less than in the wide part. But the pressure against the widest part is that of the atmosphere, hence that in the narrow part must be less, that is, a partial vacuum.

The tendency of the fluid to break up into slices is made manifest by the pulsations which, with air, produce sound, as in a trumpet, and with liquids generate undulations which may be observed when the diverging pipe is submerged.

You will find in Mr. Francis' valuable work on the hydraulic experiments at Lowell, in the United States, a very minute account of the behavior of a diverging pipe discharging water. He experimented with a pipe of which the sides diverged at an angle of 5 deg. to each other, and had the orifice at the smaller end one-tenth of a foot in diameter. He found that there was no increase of discharge after the pipe had been extended to a length of 3 feet, with an outer diameter of 0·32 foot, when the best results were obtained, namely, a discharge nearly two and a half times greater than that due to the head. In Fig. 6 I have represented one of the experiments. The head of water over the center of the pipe was only 1·18 feet, the velocity of discharge corresponding to which is 8·7 feet per second, but the actual velocity proved to be 21·15 feet per second, corresponding to a head of 6·95 feet. At the open end of the pipe the velocity fell to 2·13 feet per second, corresponding to a fall of 0·07 foot, so that during the passage of the water through three feet of pipe the kinetic energy of each pound had been reduced to nearly the $\frac{1}{100}$ part. The average kinetic energy of the contents of the pipe was 0·676 foot-pound per pound of water. The total potential energy of each pound of water was that due to the head under which the flow had taken place, namely, 1·18 feet, for that was the only motive force; hence the potential energy available for relieving the pressure on the discharge side of the orifice at the smallest part is 1·18 − 0·674 = 0·506 foot-pound per pound of water.

The contents of the pipe weigh 5·7 lb., therefore the total available potential energy was 5·7 lb. × 0·506 = 2·88 foot pounds employed in relieving the back pressure against an orifice 0·1018 foot diameter, and 0·00814 square foot area, hence the column of water which this would have represented was $\frac{2{\cdot}8 \text{ foot pounds}}{62{\cdot}2 \text{ lb.} \times 0{\cdot}00814} = 5{\cdot}69$ feet. The actual extra head induced was 5·77 feet, which includes the friction in the pipe, of which I have taken no account.

The ancient Romans, though they did not understand the principles on which diverging pipes acted, were well aware of the property they possessed in increasing the flow of water, and made use of them to get an undue supply from the gauge pipes of the public aqueducts.

It is immaterial what fluid we employ to produce the effects I have described. I have here a conical

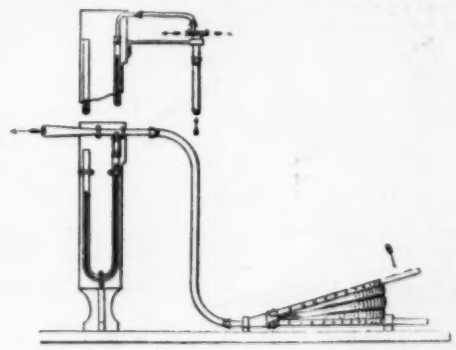


FIG. 8.

pipe, through which I allow a current of air to pass. The base of the diverging mouthpiece is connected to a siphon water-gauge; you observe that as soon as I turn on the air, the column of water in the gauge rises, indicating the formation of a partial vacuum.

I substitute a plain parallel pipe for the cone, and again let the air rush through. You see that now the gauge indicates a slight pressure in the pipe instead of a vacuum; that pressure is the measure of the friction of the air against the sides of the pipe.

If a pipe be made to terminate in the center of a flat disk, and if another disk of any light material be laid over it so as to cover symmetrically the orifice of the pipe, then if a stream of any liquid or gas be caused to flow through the pipe, it will be found impossible to blow the covering disk off, no matter how great the pressure employed. The disk will rise a little, the fluid will issue all round, a rapid pulsation, which, if the pressure be sufficient, will declare itself in a musical sound, will take place, but it will be impossible to blow the disk off. The reason is that the fluid entering the central aperture spreads out radially, and the least rise of the disk makes the area of the annular orifice by

which it escapes all round the disk greater than that of the pipe; hence the velocity of the fluid and its kinetic energy are diminished by being expended in pushing aside the atmosphere, and so keeping up a partial vacuum in the center of the disk. But this is a state of unstable equilibrium, the disk tending always to rise higher, but in so doing reducing the velocity of the escaping fluid, and increasing the vacuum, and consequently the pressure tending to hold it down, hence pulsations more or less rapid arise. By connecting the center of the disk to the siphon gauge, you see that a vacuum is at once indicated.

We must next consider the laws of impact. The consequences of impact vary according to the hardness or elasticity of the bodies striking against each other. If the bodies are elastic and do not permanently change their forms from collision, the whole of the energy of the striking body is expended in producing motion in the body struck; if the bodies are imperfectly elastic, a portion of the energy is expended in distorting or breaking up the structure of one or both bodies.

During the moment of impact of elastic bodies, that is to say, in the very brief time during which the bodies are in contact, the sum of the momenta of the two bodies is the same as it was before the impact took place. In perfectly elastic bodies, the work done in resisting compression during the first period of impact is equal to that given out during the second period, when the body regains its shape and the energy so restored is divided between the two bodies, which continue to move, but with altered velocities; there is thus no conversion of kinetic energy into any other form in the impact of perfectly elastic bodies. This is proved experimentally by the impact of two elastic balls of the same weight, such as you see suspended in this frame. The ball which strikes is brought to rest, but imparts all its energy to the ball struck, because the rebound is exactly equal to the blow.

When inelastic bodies strike each other, they do not recoil, but move on together, and the velocity of the two is found by dividing the sum of their separate moment by the sum of their masses.

$$V = \frac{M_1 V_1 + M_2 V_2}{M_1 + M_2}$$

Thus a soft body weighing 10 lb., if it strikes a body of the same weight at rest, the two will move on at half the velocity. The energy of motion in the mass of 20 lb. will, however, be only half that of the single body at a higher velocity, because energy varies as the square of the velocity and directly as the weight, hence double the weight and half the velocity will yield only half the energy, the remaining half has been expended in distorting the two bodies. I substitute two lead balls for the iron ones hanging in the frame. I cause one of the lead balls to strike the other; you see the two now swing together, and if the surfaces are examined, a bruised and distorted place will be found on each ball. In the impact of elastic bodies, because none of the energy is absorbed in permanently changing the shape of the bodies, the sum of the energies before and after collision remains the same, that is to say, the sum of the masses of the two bodies multiplied by the squares of their respective velocities remains the same after as before the impact.

Suppose a ball weighing 10 lb. strikes, with a velocity of 20 feet per second, another ball weighing 15 lb. moving in the same direction at the rate of 5 feet per second. The result will be that the velocity of the 10 lb. ball will drop to 2 feet per second, while the heavier ball will shoot forward at the rate of 17 feet per second, and the energy of motion both before and after collision will be the same, that is to say, 67·9 foot pounds. When an elastic body strikes a fixed elastic substance, the body will rebound with the same velocity with which it struck.

In oblique impacts, that is to say, when the lines of motion are inclined to each other, the velocities have to be resolved in directions parallel, and at right angles to the direction of motion of the body struck: then, according to the second law of motion, each component of the force will produce its full effect, as if no previous motion existed.

When an elastic body strikes an elastic plane surface at an angle, the direction of the blow resolves itself

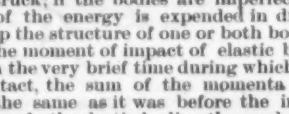


FIG. 9.

into motion along the plane, and at right angles to it. According to the first law of motion, the velocity along the plane will continue uniform, while we have just seen that an elastic body striking a fixed one at right angles rebounds with the same velocity with which it struck; hence the conditions are exactly reversed with respect to the motion at right angles to the plane, but unaltered with respect to the motion along the plane, and, therefore, the body will glance off at the same angle as that at which it struck.

If you watch a game of billiards, you will see the laws I have laid before you illustrated in endless variety although the conditions are unfavorable, because the balls and cushions are not perfectly elastic. The balls often have a twist, while the friction of the table and resistance of the air interfere with the uniformity of velocity.

When we speak of perfectly elastic substances, we do not mean those which, like India-rubber, have a great range of elasticity, but those, like glass and hard metals, which cannot be deformed, because the elastic limit approaches very nearly that of the ultimate strength or strain-producing rupture.

I have stated that in the impact of elastic bodies no energy is expended in the deformation of the bodies, but that all is employed in producing visible motion. This is not strictly correct. When the balls in this apparatus strike, you hear a sound; that sound is caused by the vibration of the substance of the balls communicated to your ears through corresponding vibrations of the air; the energy necessary to produce these secondary motions is lost, so far as any effect it can produce on the visible motion is concerned. If the impacts were sufficiently frequent, the work expended in internal vibration of the balls would be competent to stop the motion were all the other resistances abolished.

This consideration is of importance in the theories relating to the ultimate structure of matter, and was dwelt upon at some length by Sir William Thomson in his recent address to the British Association.

ORANGES IN PALESTINE.

CONSUL MERRILL, of Jerusalem, states in his last report on fruit cultivation in Palestine that the orange groves in that country are confined chiefly to Jaffa and Gaza, and are situated near the sea coast. The trees appear to flourish best near the sea, the beach sand mingled with alluvial soil being best adapted to their growth. There are, in Jaffa alone, no less than 500 different gardens, containing, altogether, about 800,000 trees, both large and small. Of these gardens, 150 are ranked as first-class, while the others are ranked as second and third rate in size and production. The trees are planted about 15 feet apart, although there is no regularity or exactness on the part of the natives in planting them. In July or August, cuttings are made from the sweet lemon trees, each about 18 inches long, and these are planted in beds and watered twice a day. They grow rapidly, and in the second year they are budded. When the bud has taken, the lemon stalk is cut off, a few inches above the bud, and the new shoots begin to bear in the third or fourth year. The trees continue bearing for twenty or thirty years. During the summer every tree is watered once a week, and in some cultivations it is a rule to water the trees every fifth day. Water is brought to the surface from a depth of twenty-five or thirty feet, by means of horse power, the owner of the garden employing for this work horses, donkeys, or camels. The cost of irrigation, with which it is customary to reckon the other expenses that are necessary to keep the ground in order, is estimated at about one-fifth of the value of the crop in gardens of the first class, while in the inferior gardens it amounts to one-third and sometimes one-half of the value of the crop. The orange trees in Palestine do not suffer from any noxious insects, fungous growth, or diseases of any kind, and both the climate and soil are admirably adapted to produce healthy trees. In planting, the ground between the trees is generally cultivated, small fruits or vegetables being grown where the branches do not touch each other. Interspersed among the orange trees are frequently seen palm trees, bananas, the apple, peach, plum, pear, apricot, or fig, and occasionally the mulberry and sycamore. The average cost to the producer of 1,000 oranges is estimated to be about 21s., and capital invested in orange gardens is expected to return between 12 and 15 per cent. For 1,000 oranges it is customary to reckon 1,500, so that after they are assorted the purchaser will have, out of 1,500, 1,000 that are fit for exportation. They are consigned in large quantities to Europe, and among the different markets, that of Odessa is becoming the most important for Jaffa oranges. Thousands of boxes are also annually sent to London. Consul Merrill says that besides the Jaffa orange proper, which is the only description exported, and is of oval or lemon shape, and very large, there is another kind cultivated in Palestine. This grows upon trees that are grown directly from the seed of the orange, without budding or grafting. They are small and of inferior quality, and are all consumed at home.

THE TREATMENT OF CHOLERA.

THE *Practitioner* contains the concluding paper of the interesting series that have been published in that journal by Drs. Lauder Brunton and Pye-Smith, in the course of which they have discussed the present knowledge of the pathology of cholera. Speaking of the treatment of the disease, they divide remedies into five classes; of these, three contain remedies which act on the intestine. They are: 1. Those which are likely to have an antiseptic action on the intestine by destroying any organisms there present, such as carbolic acid and its allies, sulphurous acid, nitro-muriatic acid, hyposulphites, permanganates, chlorine, chloralum, turpentine, salts of copper, boracic acid, calomel, and corrosive sublimate. The cholagogue action of calomel is thought to be of service by inducing indirectly the antiseptic action of bile. 2. Those remedies which will tend to remove the cholera poison, whether it consists of living organisms or of some chemical substance, exemplified by the treatment by castor oil and other purgatives. 3. Those remedies which will counteract the effect of the poison upon the intestinal canal, as opium, morphia, ice water, belladona, cannabis indica, chloroform, chloral, carminatives, and astringents. 4. Remedies which will tend to eliminate the poison from the system, as copious draughts of water (as diuretic) and purgatives. 5. Those remedies which will counteract the effects of the poison, viz., intravenous injection of saline fluids and other substances, and various measures to restore the circulation by acting upon the skin. In dealing with the premonitory diarrhœa, Cantani's method of injections, by means of the long intestinal tube, of laudanum and tannic acid is described. The authors consider that Ferran's results of inoculation are more favorable than could have been expected, and point out the following as "directions in which further researches after a remedy for cholera are most likely to prove successful": 1. The discovery of an antiseptic which will destroy pathogenic organisms in the intestine and prevent the formation of the cholera poison, while they are not themselves poisonous. Corrosive sublimate is a sufficiently powerful antiseptic, but it may itself prove poisonous to the patient as well as to the pathogenic organisms. It is possible that among the members of the aromatic group of bodies some substance may be found having the desired properties. 2. The discovery of some substance which will antagonize the action of the cholera poison after its absorption. As a preliminary step in this direction further experiments are needed in the nature and action of alkaloidal substances obtained from cholera dejecta, as well as from artificial cultivations on various media and under various conditions, electrical and otherwise. 3. Observations on the effect of stimulation of the mesenteric plexus by currents passed through the uninjured abdomen in poisoned animals and patients suffering from the disease."

TREATMENT OF NEURALGIA BY NEUBER'S METHOD.

DR. SCHAPIRO recently read a paper, at the Medical Society of St. Petersburg, upon the results of researches on treatment of neuralgia by Neuber's method of hypodermic injections of a solution of osmic acid. His observations include eight cases of trigeminal neuralgia (three males and five females). The age of the patients varied from thirty-eight to sixty. In every case the disease was of a very severe type, and of long standing. The result of the treatment was complete cure in five cases (three females and two males), great alleviation of the pain in two cases, and no success at all in one case (female). The number of injections made in each case was from one to twelve (twenty in one case), five to ten drops being injected every time. The duration of the treatment was from one to sixty days. Dr. Schapiro adopts a modification of Neuber's 1 per cent aqueous osmic solution on account of the osmic acid soon undergoing decomposition in a watery solution. After a whole series of combinations, he concluded that an addition of glycerine to the watery solution prevents for a long time osmic acid from undergoing any change. In not one of the cases treated by him was an injection followed by any ill effect. The patients are now under the author's observation (two to six months after the commencement of the treatment).—*Lancet.*

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TABLE OF CONTENTS.

PAGE

I. ENGINEERING AND MECHANICS.—English and French Armor Clad Ships..... 7943
A Proposed War Balloon.—3 figures..... 7943
Engineering Progress in 1884.—Report of the Convention of the American Society of Civil Engineers..... 7943
Coppin's Triple Steamships.—5 figures..... 7945
American Dredgers and Excavators.—Full page of illustrations.. 7945
Improved Calculating Machine.—2 figures..... 7948

II. TECHNOLOGY.—On the Purification of Water by Iron on a Large Scale.—By W. ANDERSON..... 7948
The Preparation of Hyposulphurous Acid, and its Use in the Developer for Dry Plates..... 7949

III. ELECTRICITY, HEAT, ETC.—A New Fire Alarm.—1 figure..... 7953
Jablochkoff's Auto-Accumulator..... 7953
Gime's Accumulator.—1 figure..... 7953
The Forms of Vibrating Bodies.—A Study of molecular motion caused by electricity.—19 figures..... 7954
On the Conversion of Heat into Useful Work.—A long and interesting article by WM. ANDERSON..... 7955

IV. ARCHITECTURE.—Slate Roof Coverings.—Characteristics of good slate.—Sizes of slate.—Laying slate..... 7961
New Mode of Building Sustaining Walls.—2 figures..... 7962
The Hooping of the Dome of St. Peter's, Rome..... 7962

V. GEOLOGY.—The American Oil and Gas Fields.—Paper read before the Society of Arts by Prof. J. DEWAR.—Manner of obtaining oil.—Tracts where it is found.—Relations of gas to oil.—Analyses of gas.—Russian compared with American oil..... 7949

VI. MEDICINE, ETC.—The Treatment of Cholera..... 7958
Treatment of Neuralgia by Neuber's Method..... 7958

VII. MISCELLANEOUS.—Oranges in Palestine..... 7958

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